# PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

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VOLUME 118
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NATIONAL SCIENCE FOUNDATION

JOINT OCEANOGRAPHIC INSTITUTIONS, INC

118

## DRILLING LOCATIONS

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| 101 | Bahamas | 626–636 |
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| 103 | Galicia Margin | 637–641 |
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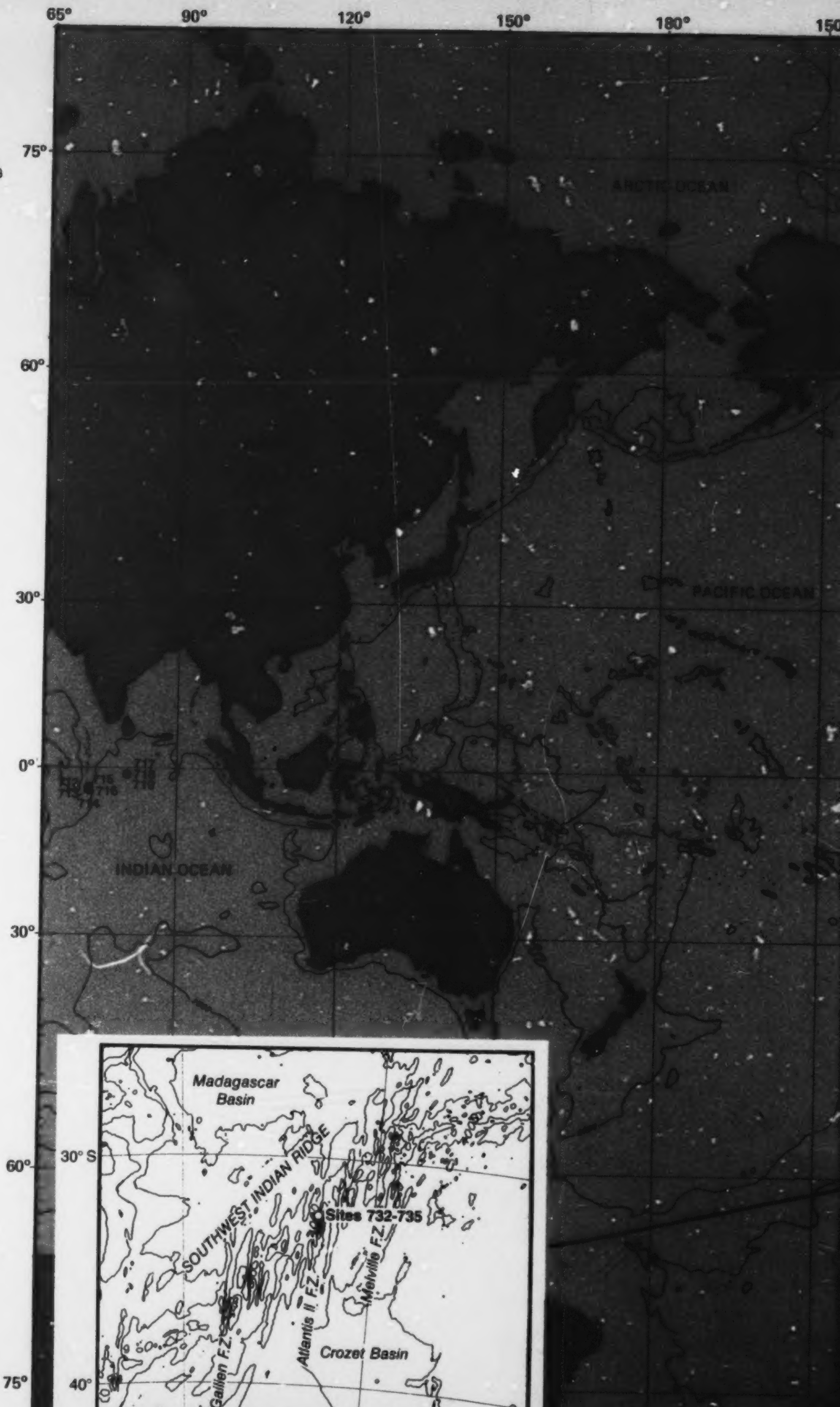
| 118 | Southwest Indian Ridge | 732–735 |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ARCTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
715
716
717
718
719
714
Madagascar Basin
30° S
SOUTHWEST INDIAN RIDGE
Sites 732-735
Melville F.Z.
Atlantis II F.Z.
Gallieni F.Z.
Crozet Basin
40°
50° E
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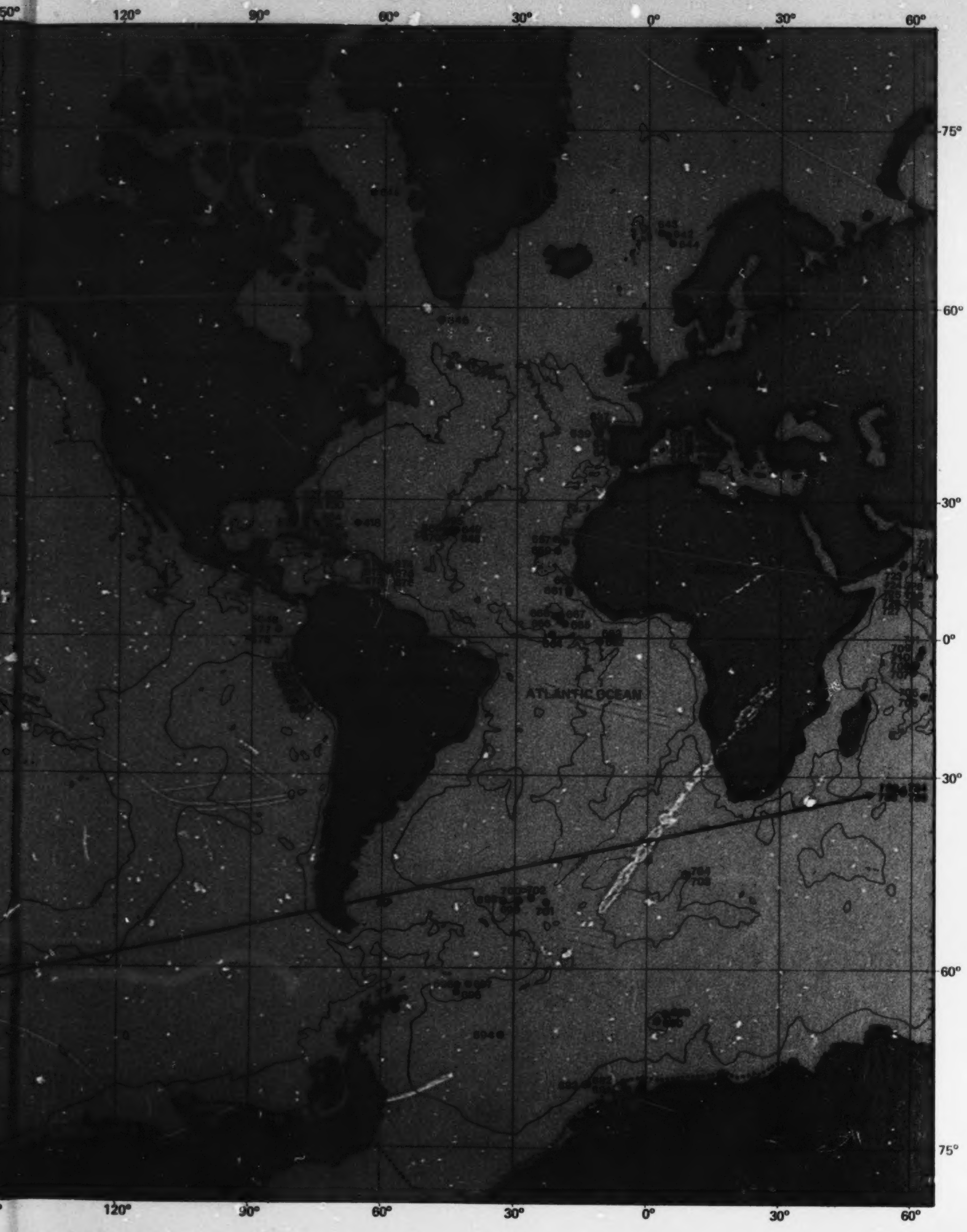
# OCEAN DRILL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**LING PROGRAM**

# PROCEEDINGS
# OF THE
# OCEAN DRILLING
# PROGRAM

## VOLUME 118
## INITIAL REPORTS

## FRACTURE ZONE DRILLING ON THE SOUTHWEST INDIAN RIDGE

Covering Leg 118 of the cruises of the Drilling Vessel *JOIDES Resolution*,
Port Louis, Mauritius to Port Louis, Mauritius, Sites 732–735,
17 October to 14 December 1987

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# Foreword

### By the National Science Foundation

The scientists of the Ocean Drilling Program (ODP) have embarked on what could prove to be one of the most important earth science initiatives of the decade—an initiative rivaling in scope and impact the exploration of the frontiers of outer space. The program explores our planet's last frontier—the Earth's structure and history as it is revealed beneath the oceans. The scope of the program's scientific goals excites the imagination, challenges the intellect, and enhances the spirit of cooperation among peoples in countries around the world.

Between 1872 and 1876, HMS *Challenger* undertook the world's first major oceanographic expedition. That expedition greatly expanded man's knowledge of the world's oceans and revolutionized our ideas about planet Earth. From 1968 to 1983, another ship named *Challenger* logged more than 375,000 miles on 96 voyages across every ocean for the Deep Sea Drilling Project (DSDP), operated by Scripps Institution of Oceanography. Among the project's many remarkable discoveries were the confirmation of seafloor spreading and the establishment of the relative youth of the seafloor, thus verifying the dynamic and changing nature of the Earth's crust.

Today, the Ocean Drilling Program, which began in 1983, brings new resources to bear on scientific ocean drilling. A new drillship is in operation—the *JOIDES Resolution*—one of the world's most modern and best equipped drillships with enhanced capability for drilling and coring in polar areas and rough weather, expanded laboratory space, facilities for more scientists, and a major drill-hole logging program. The name of the ship was derived from the international scientific partnership that directs the program—the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES)—and from the flagship of Captain Cook's second voyage to the Pacific Ocean in the late 18th century. Texas A&M University is responsible for science operations in the program, and Lamont-Doherty Geological Observatory is responsible for the logging program.

The Ocean Drilling Program truly has international participation. In 1975, the International Phase of Ocean Drilling began with member nations—the U.S.A., U.S.S.R., the Federal Republic of Germany, Japan, the United Kingdom, and France—all providing funds and scientific guidance for the project. Today, ODP partners include the U.S.A., Canada, France, the Federal Republic of Germany, Japan, the United Kingdom, and the European Science Foundation, which represents Sweden, Finland, Norway, Iceland, Denmark, Belgium, the Netherlands, Spain, Switzerland, Italy, Greece, and Turkey. The National Science Foundation, with funds contributed by the United States and international partners, supports the scientific operations and planning for the ODP through a contract with Joint Oceanographic Institutions, Inc. (JOI).

The information gained by the program leads to a better understanding of the Earth and its dynamic processes. Drilled sediment cores and logs reveal clues to past climatic history and tie into parallel studies of paleoclimates from glacial ice cores drilled on the continents. Understanding these sediment cores will enable scientists to complete the map of major geologically active regions of the Earth, and to identify processes that lead to dynamic change such as earthquakes, volcanic eruptions, and mountain and continental growth. We are far from being able to predict such changes accurately now; but with the new tools and understanding, the accuracy of such predictions can be improved. This better understanding of the Earth's system(s) will allow us to identify regions of potential mineral and energy resource development, an issue of worldwide human interest. The Ocean Drilling Program is not in itself aimed at finding resources, but the knowledge of the Earth's processes that is gained through such a basic research program will inevitably provide pieces of information required for such resource discovery and exploitation.

The program is fully under way in its aim to further the understanding of the Earth's dynamic systems. People of our planet will benefit directly and indirectly from this research in both their daily living and work activities. This multinational endeavor will perhaps foster other cooperative efforts in science or among societies. The Ocean Drilling Program has distinguished ancestors in the original *Resolution* and *Challenger* expeditions and the Deep Sea Drilling Project. The National Science Foundation is proud to be playing a leading role in this program, and we are looking forward to significant and innovative science for many years to come.

Erich Bloch
Director
National Science Foundation

Washington, D.C.

# Foreword

## By Joint Oceanographic Institutions, Inc.

This volume presents results from the Ocean Drilling Program (ODP), where scientists use a specially equipped ocean drilling ship to sample and measure the properties of the submerged part of the Earth's crust. These data are then synthesized with other information to yield new insights into earth processes.

These results address the scientific goals of the program, which include providing a global description of geological and geophysical structures and materials, studying in detail areas of major geophysical activity such as mid-ocean ridges and the associated hydrothermal circulations, and studying passive and active continental margins. In addition, the ODP data support the study of sea-level and ocean-circulation changes, the effects of the Earth's orbital variations on climate, and the study of processes and mechanisms of evolution from the biological records in the cores which are recovered from drilling.

The Ocean Drilling Program is a partnership of scientists and governments. Overall scientific policy and management guidance is provided by Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), which consists of committees and panels made up of representatives of the participating institutions and other scientific and engineering experts. The JOIDES Executive Committee (EXCOM) provides general oversight; the JOIDES Planning Committee (PCOM) is the focal point for all scientific planning for the ODP and is key to the scientific success of the program.

The PCOM has a network of panels and working groups which screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. PCOM uses the recommendations of these panels and committees to select drilling targets, to specify the major scientific objectives of each two-month drilling segment or leg, and to provide the science operator with nominations for co-chief scientists. The science operator, Texas A&M University, in turn is responsible for planning the detailed ship's operations, actual drilling schedules, and final scientific rosters, which are developed in close cooperation with PCOM and the cognizant panels.

Many of the scientific goals can be met only with new technology. Thus the program has identified engineering goals, which include the ability to start a hole and to core on bare rock at mid-ocean ridge sites, to drill in high-temperature and corrosive regions typical of hydrothermal areas, and to core in high latitudes with minimum interference from high seas and sea ice. To meet these needs, the program operates a specially equipped drillship, the *JOIDES Resolution*, which contains laboratories and equipment that are state-of-the-art, and carries a major new logging program.

The ship, registered as SEDCO/BP 471 after her owners and her length in feet (144 meters), is 70 feet (21 meters) wide, and has a displacement of 16,595 long tons. Her derrick towers 200 feet (61 meters) above the waterline, and a computer-controlled dynamic-positioning system stabilizes the ship over a specific location while drilling in water depths up to 27,000 feet (8230 meters). The drilling system collects cores from beneath the seafloor with a derrick and drawworks that can handle 30,000 feet (9144 meters) of drill pipe. More than 12,000 square feet (1115 square meters) of space distributed throughout the ship is devoted to scientific laboratories and equipment. The ship sails with a scientific and technical crew of 50 and a ship's crew of 65.

Logging is a major part of the overall operation. The program provides a full suite of geochemical and geophysical measurements for every hole deeper than 1300 feet (400 meters). For each such hole, there are lowerings of basic oil-industry tools: nuclear, sonic, and electrical. In addition, a borehole televiewer is available for imaging the well-bore wall, a 12-channel logging tool provides accurate velocity and elastic property measurements as well as sonic waveforms for spectral analysis of energy propagation near the well bore, and a vertical seismic profiler records reflectors from below the total depth of the hole.

Texas A&M University serves as science operator for the Ocean Drilling Program. In this capacity, they operate and staff the drillship to collect cores from JOIDES-designated sites from around the world. The science operator also ensures that adequate scientific analyses are performed on the cores by maintaining the shipboard scientific laboratories and by providing logistical and technical support for shipboard scientific teams. Onshore, Texas A&M manages scientific activities after each leg, is curator for the cores, distributes samples, and coordinates the editing and publication of the scientific results. Lamont-Doherty Geological Observatory (LDGO) of Columbia University manages the program's logging operations, which include processing the data and provision of assistance to scientists in data analysis. The ODP Data Bank, a repository for geophysical data, is also managed by LDGO. Core samples from ODP and the previous Deep Sea Drilling Project are stored for future investigation at three sites: ODP Pacific and Indian Ocean cores at Texas A&M University, ODP and DSDP Atlantic and Antarctic cores at Lamont-Doherty Geological Observatory, and DSDP Pacific and Indian Ocean cores at Scripps Institution of Oceanography.

International oversight and coordination are provided by the ODP Council, a governmental consultative body of partner country representatives, chaired by the United States, which periodically reviews the general progress of the program and discusses financial plans and other management issues. Joint Oceanographic Institutions, Inc., a nonprofit consortium of U.S. oceanographic institutions, serves as the National Science Foundation's prime contractor and manages the ODP. JOI is responsible for seeing that the scientific objectives and plans are translated into scientific operations consistent with JOIDES recommendations and budgetary constraints.

Scientific achievements of the ODP already include new data on early seafloor spreading and how continents separate and their margins evolve. We have new insight into glacial cycles and the fluctuations of currents throughout geological time. Technical achievements include the first bare-rock coring, and logging data more accurate and complete than ever before. JOI is pleased to have played a facilitating role in the Ocean Drilling Program.

D. James Baker
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[1] Includes member organizations during time of cruise.

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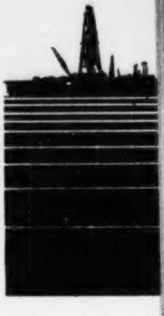
# SECTION 1: INTRODUCTION



# 1. INTRODUCTION AND EXPLANATORY NOTES[1]

Shipboard Scientific Party[2]

## INTRODUCTION

Leg 118 of the Ocean Drilling Program began in Mauritius on 22 October 1987 and ended there on 14 December 1987. The aim of the leg was to drill one or more holes in the Atlantis II Fracture Zone of the Southwest Indian Ridge. The primary goals were (1) to drill a deep (500+ m) hole in exposed upper mantle peridotite on a median ridge of the fracture zone with the aid of a hard-rock guidebase and (2) to conduct a major program of geophysical logging and other downhole measurements. If a deep hole at this site could not be achieved, other locations on the walls and floor of the fracture zone would be attempted. Secondary objectives were (1) to drill a series of shallow basement holes across the floor of the fracture zone and (2) to sample basement in active and fossil nodal basins.

### Scientific Objectives

Fracture zones are ubiquitous features of the oceanic lithosphere, yet little is known regarding their petrology, structure, or tectonic evolution. Recent models for ridge dynamics (e.g., Schouten and Klitgord, 1982) suggest that fracture zones play a major role in segmentation of spreading ridges. These zones are considered to be relatively cold zones that separate stationary spreading-center cells beneath spreading-ridge segments. Crustal magma chambers are believed to lie beneath the spreading cells, and new crust is formed by crystallization along the walls of the magma chambers and by vertical and lateral injection of magma along the spreading ridge. In this model, less magma will reach the edges of the spreading cells (i.e., fracture zones), which leads to thinner crustal sections. Such thinning of oceanic crust in the vicinity of fracture zones was demonstrated by seismic studies along the ridge axes (e.g., Detrick and Purdy, 1980; Fox et al., 1980; Cormier et al., 1984). In some cases, the crustal thickness, particularly beneath nodal basins, may be less than 5% to 10% of normal sections.

Because of these relatively thin crustal sections and the great topographic relief of many fracture zones, mantle and lower crustal rocks are commonly exposed on their floors and walls. The abundance of plutonic rocks in fracture zones appears to correlate closely with the spreading rate of the associated ridge. For example, peridotites compose more than 65% of all material dredged from fracture zones of the very slow-spreading Southwest Indian Ridge, whereas they make up only 10%–15% of dredge hauls from typical fracture zones of slow-spreading ridges and are nearly absent from those of the fast-spreading East Pacific Rise (H. Dick, unpubl. data, 1987). Considering the difficulty of achieving deep penetration in normal ocean crust, fracture-zone drilling provides one of the best possibilities for obtaining *in-situ* samples and stratigraphy of the lower crust and mantle.

Abyssal peridotites dredged from spreading ridges and fracture zones are generally regarded as residues of partial melting of mantle material from which mid-ocean ridge tholeiite magmas have been extracted. We expected that drilling in fracture zones would allow us to sample petrologically related basaltic, gabbroic, and ultramafic rocks. Study of such cores should lead to a better understanding of the processes of partial melting in the mantle, melt extraction, and later modification in shallow magma chambers.

Other general objectives of this fracture-zone drilling were as follows:

1. To determine the lateral and vertical variability of rock types on the floor of the fracture zone.
2. To investigate the nature and distribution of deformation in a fracture zone and to determine whether there is a single slip plane, multiple planes, or penetrative slip across the entire width of the feature.
3. To determine the thermal structure of transform-generated crust and to assess the extent of alteration and seawater penetration.
4. To determine the nature and thickness of oceanic crust in the nodal basins where the ridge crests meet the transform fault.
5. To determine the physical properties, magnetism, and seismic velocities of transform-generated crust and, particularly, to document any anisotropy in these properties.

### Geologic Background

The Atlantis II Fracture Zone is one of a series of major transform faults that offset the very slow-spreading Southwest Indian Ridge (Figs. 1 and 2). This 210-km-long feature trends roughly north-south and crosses the ridge at approximately 57°E. Spreading on the Southwest Indian Ridge is very slow, on the order of 0.8 cm/yr (Fisher and Sclater, 1983).

The *Conrad* cruise 27-09 (H. Dick, Chief Scientist) conducted a detailed survey of the fracture zone and adjacent ridge segments in October 1986. Sea Beam echo sounding, seismic-reflection profiling, magnetics, and gravity were run along closely spaced tracks (5 km) parallel to the fracture zone, with nearly complete coverage over a 55-km-wide strip. The southern and northern rift valleys of the offset spreading ridge are well defined, with over 2200 m of relief and widths of 22 and 38 km, respectively (Fig. 3). A line of small axial volcanoes marks the southern ridge crest. Well-defined nodal basins, lying on the transform side of today's neovolcanic zone, mark the intersections of the transform and ridge axes.

The transform valley is about 30–40 km wide, as measured between the slope breaks from normal ridge topography to the steep transform walls. The valley floor systematically deepens from about 5 to 6 km and narrows from 14 to 7.5 km between north and south. The spreading rate, as determined from the magnetic anomalies mapped to the east and west of the transform, has been about 10 mm/yr over the last 20 m.y. The magnetic anomalies created since anomaly 5 appear to extend into the transform valley near today's inferred slip zone.

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

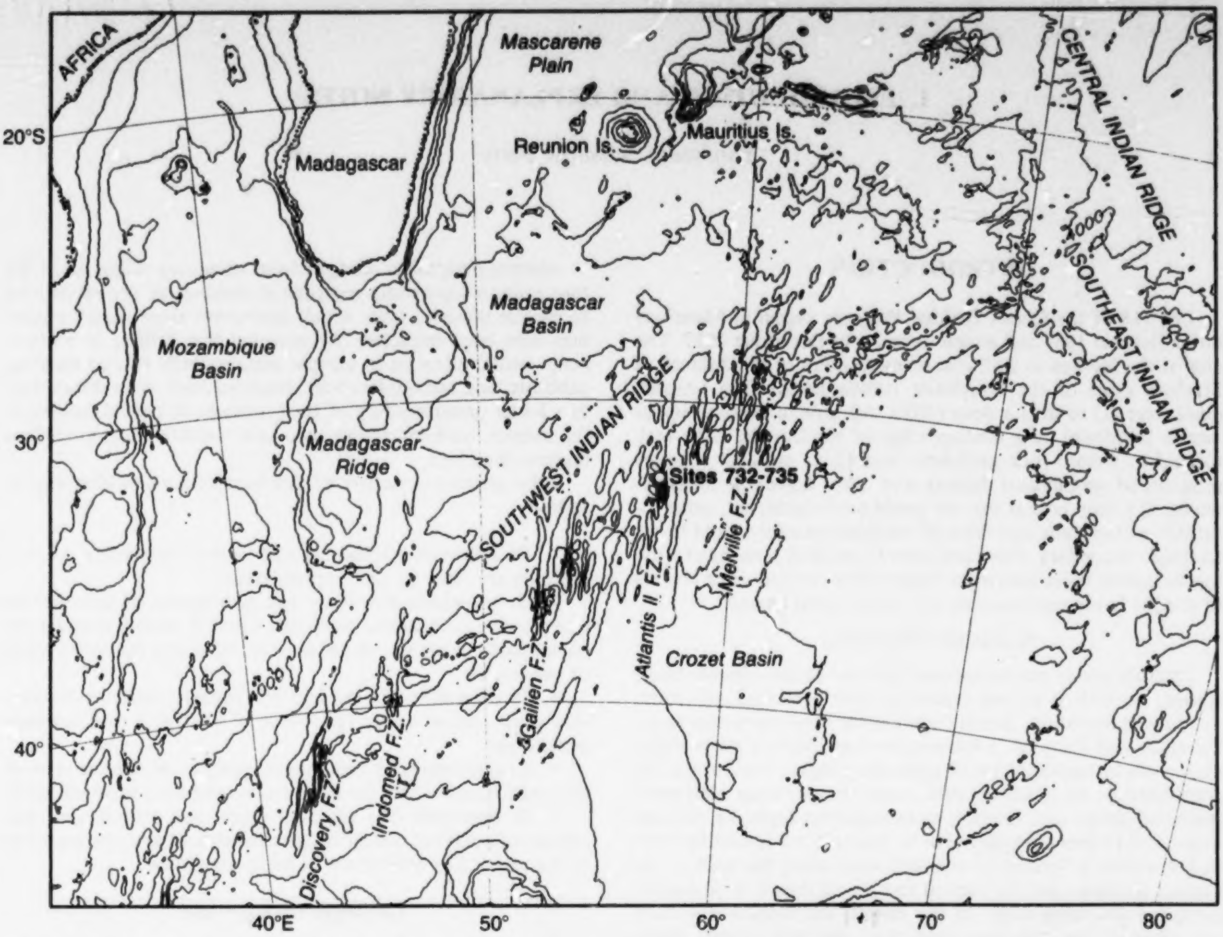


Figure 1. Bathymetric map of the southern Indian Ocean showing the location of sites drilled during Leg 118. Contours in 1000-m intervals.

Relief on the transform valley is on the order of 5800 m, and the walls of the transform valley are remarkably steep (typically, 30°–40°), although locally, these walls may be much more subdued, particularly along the western side of the valley. The deepest point is 6480 m in the southern nodal basin, and the shallowest is an uplifted bench on the eastern transverse ridge at 680 m.

A bathymetrically prominent "median tectonic ridge" bisects the northern half of the transform valley and can be followed intermittently down the southern half as well (Fig. 3). In the north, this ridge shoals to 4200 m and has a relief of between 1000 and 1500 m, whereas in the southern half, the relief drops abruptly to only a few hundred meters. In this area, two deep (6.3 km), flat-floored, sedimented basins 2.5 × 24 km and 4 × 18 km are divided by a relatively low (120–250 m) median tectonic ridge. Seismic-reflection profiles along the axes of these basins and across the median tectonic ridge show stratified sediments that are at least 120 m thick in the centers of the basins and that appear to onlap and possibly drape the intervening ridge. A piston core into each of these basins recovered 3 m of sand and pebbly gravel having clasts up to 2 cm in diameter. Each of the trigger cores contained pelagic ooze, and we believe that before the piston core was washed during recovery, the original sediment consisted of a mixture of pebbles, sand, and pelagic ooze.

Dredging of the walls and floor of the fracture zone during the site survey yielded chiefly ultramafic rock and lesser amounts of gabbro, basalt, and greenstone. In all, 2100 kg of rock was recovered from 35 dredge hauls. Peridotite is the dominant lithology in about one-third of these hauls. Four dredge hauls along the median tectonic ridge recovered serpentinized peridotite, gabbro, metamorphosed basalt, and diabase, which suggests that this feature is the locus of extensive hydrothermal alteration and emplacement of serpentinized mantle peridotite. One dredge haul from the southern end of the median ridge recovered only peridotite. Virtually all of the basaltic rocks recovered have been altered, and this alteration was usually oxidative, with many of the rocks stained a bright red or white. In addition, some unusual breccias cemented by a black tarry-appearing hydrothermal oxide were recovered. These observations suggest that the conditions of hydrothermal alteration along the transform plate boundary may differ substantially from those occurring along ocean ridges.

The *Conrad* survey extended about 85 km into the fracture zone trace north of the transform. Curvilinear bathymetric trends along the east wall reflect the transition from seafloor material created at the ridge crest to that formed in the transform (Fig. 3). Two sedimented basins, 4.5 to 5 km deep and 10 to 20 km wide, were found along this part of the fracture zone floor. In one of these basins, several heat-flow measurements were per-

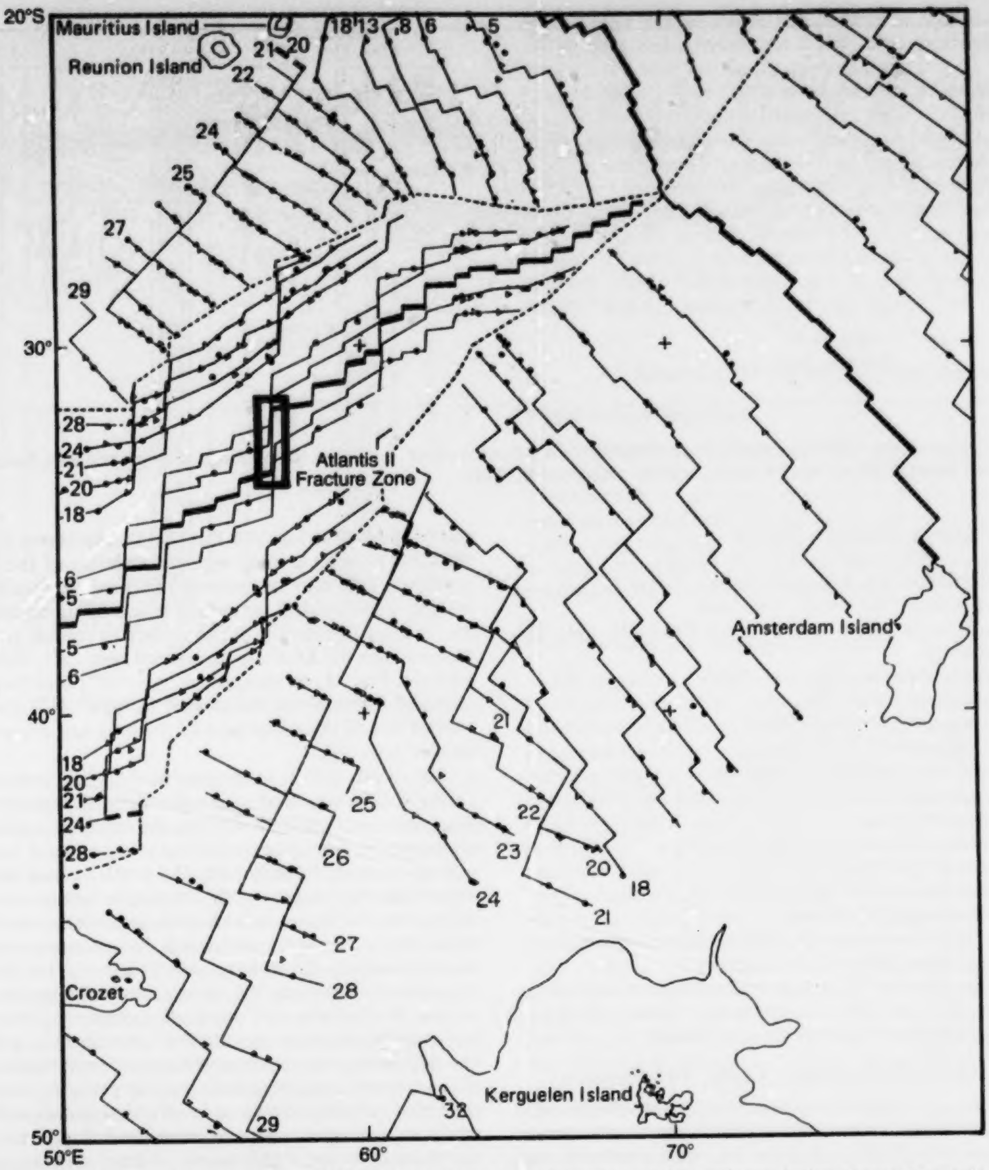

20°S
Mauritius Island
Reunion Island
21
20
22
18
13
8
6
5
24
25
27
29
30°
28
24
21
20
18
Atlantis II
Fracture Zone
6
5
5
6
40°
18
20
21
24
28
Amsterdam Island
21
25
22
26
23
20
18
24
21
27
28
Crozet
Kerguelen Island
32
29
50°
50°E
60°
70°

Figure 2. Atlantis II Fracture Zone within the plate tectonic configuration of the southwest Indian Ocean. Magnetic anomalies after Patriat et al. (unpubl. data, 1987). Dashed lines show past plate boundaries. Box shows area of Figure 3.

formed, and a piston core of pelagic ooze was recovered. The obtained heat-flow values ranged from about 15 to 115 mW/m$^2$, with most values toward the lower end.

## EXPLANATORY NOTES

### General Information

The following notes are intended to aid interested investigators in understanding the terminology, labeling, and numbering conventions used by the Ocean Drilling Program during Leg 118. In general, Leg 118 followed the precedents set by Legs 106, 109, and 111 for drilling basement holes.

### Authorship of Site Reports

The separate sections of the Site Reports, where appropriate, were written by shipboard scientists as follows (authors are listed in alphabetical order in parentheses; no seniority is necessarily implied):

Site Summary (Robinson, Von Herzen)
Background and Scientific Objectives (Robinson, Von Herzen)
Geologic and Tectonic Setting (Robinson, Von Herzen)
Operations (Adamson, Von Herzen)
Sedimentology (Swift)
Biostratigraphy (Gard)

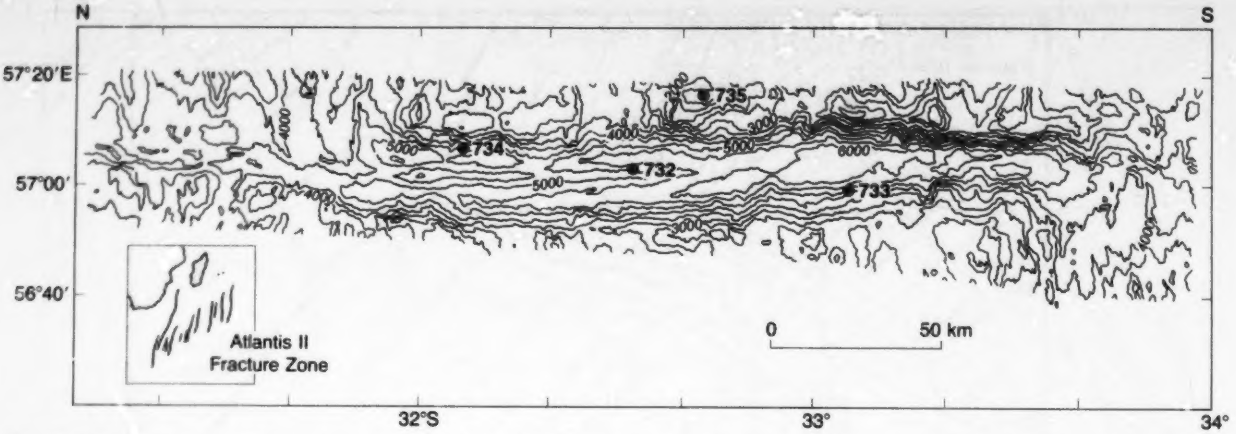


Figure 3. Bathymetric map at 500-m contour intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

Lithostratigraphy (Bloomer, Meyer)
Structure and Deformation (Cannat, Dick)
Petrography (Bloomer, Kempton, Meyer, Ozawa)
Oxide and Sulfide Mineralogy (Natland)
Metamorphism and Alteration (Cannat [Sites 732-734], Hebert, Stakes)
Geochemistry (Emmermann, Hertogen)
Paleomagnetics (Kikawa, Pariso)
Physical Properties (Itturino, Kirby)
Thermal Conductivity (Von Herzen)
Temperature Measurements (Scott)
Schlumberger Logs (Goldberg, Kassenaar)
Sonic Logs (Goldberg)
Vertical Seismic Profiling (Hoskins, Swift)
Magnetometer Logs (Pariso, Scott)
Permeability Experiments (Becker)
Borehole Televiewer (Goldberg)
Summary and Conclusions (Robinson, Von Herzen)
Sedimentary Barrel Sheets (Gard, Swift)
Igneous Barrel Sheets/Thin-Section Descriptions (Adamson, Bloomer, Cannat, Dick, Emmermann, Hebert, Hertogen, Kempton, Meyer, Natland, Ozawa, Stakes)

## Numbering of Sites, Holes, Cores, and Samples

ODP drill sites are numbered consecutively from the first site drilled by the *Glomar Challenger* in 1968. A site number refers to one or more holes drilled while the ship was positioned over one acoustic beacon. Multiple holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of hole), moving the ship some distance from the previous hole, and then drilling another hole.

The first hole drilled at an ODP site is assigned the site number modified by the letter A. Subsequent holes at the same site are designated with the site number modified by letters of the alphabet assigned in chronological sequence of drilling. Note that this differs slightly from the DSDP practice of designating the first hole at a given site by the site number, unmodified, and subsequent holes by the site number modified by letters of the alphabet. It is important, for sampling purposes, to distinguish among holes drilled at a site because recovered sediments or rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

Three varieties of coring system were employed during Leg 118. The Rotary-Coring System (RCB) was the basic system used. Two types of coring motors were also used on the lower end of the drill string. The Positive Displacement Coring Motor (PDCM) permits drilling without rotation of the bottom-hole assembly; core may be recovered by wireline as with the rotary system. The Navidrill permits similar drilling capability, but the motor must be brought to the surface to recover core. Cores recovered with the RCB are designated type "R"; those recovered with the PDCM are designated type "D"; and those recovered with the Navidrill are designated as type "N." Loose cuttings washed out of the upper part of the hole and recovered are designated type "W."

The RCB, which is the standard coring device used since DSDP Leg 1, was used with roller-cone and special hybrid bits designed specifically for drilling the types of rock we expected to encounter during Leg 118. The cored interval is measured in meters below seafloor (mbsf). The depth interval assigned to an individual core begins with the depth below the seafloor at which the coring operation began, and extends to the depth at which the coring operation ended. For example, each coring interval is usually 9.5 m long, which is the nominal length of a core barrel; however, the coring interval may be shorter or longer. "Cored intervals" need not necessarily abut one another, but may be separated by "drilled intervals." In soft sediment, the drill string may be "washed ahead" with the core barrel in place, but not recovering sediment, by pumping water down the drill pipe at high pressure to wash the sediment out of the way of the bit and up the space between the drill pipe and the wall of the hole; however, if thin layers of hard rock are present, it is possible to get "spotty" sampling of these resistant layers within the washed interval, and thus have a cored interval greater than 9.5 m. In drilling hard rock, a center bit may replace the core barrel if it is necessary to drill without core recovery.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored intervals in meters below seafloor usually are unique in a given hole; however, this may not be true if an interval must be cored twice, due to caving of cuttings or other hole problems. Nominally, a completely recovered core consists of 9.3 m of rock or sediment contained in a plastic liner (6.6 cm internal diameter) plus about 0.2 m (without a plastic liner) in the core catcher. The core catcher is a device at the bottom of the core barrel that prevents the core from sliding out when the barrel is being retrieved from the hole.

A recovered core is divided into 1.5-m sections, which are numbered serially from the top (Fig. 4). When complete recovery is obtained, the sections are numbered from 1 through 7,

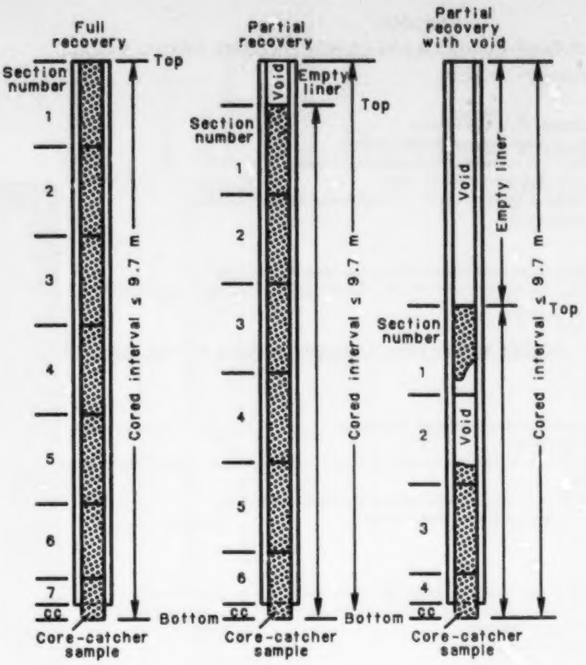


Figure 4. Diagram showing procedure used for cutting and labeling core sections.

with the last section possibly being shorter than 1.5 m (rarely, an unusually long core may require more than seven sections). When less than complete recovery is obtained, there will be as many sections as needed to accommodate the length of the core recovered; for example, 4 m of core would be divided into two 1.5-m sections and a 1-m section. If cores are fragmented (recovery less than 100%), sections are numbered serially and intervening sections are noted as void, whether or not shipboard scientists believe that the fragments were contiguous *in-situ*. Material recovered from the core catcher is placed below the last section when the core is described and then labeled core catcher (CC); in sedimentary cores, it is treated as a separate section. Scientists completing visual core descriptions describe each section as a physical unit; one or more lithologic boundaries may occur anywhere within this physical unit and are not considered when core is assigned sections.

A recovered basalt, gabbro, or peridotite core also is cut into 1.5-m sections, which are numbered serially; however, each piece of rock is then assigned a number (fragments of a single piece are assigned a single number, with individual fragments being identified alphabetically). The core-catcher sample is placed at the bottom of the last section and is treated as part of the last section, rather than separately. Scientists completing visual core descriptions describe each lithologic unit, noting core and section boundaries only as physical reference points.

When, as is usually the case, the recovered core is shorter than the cored interval, the top of the core is equated with the top of the cored interval by convention, to achieve consistency in handling analytical data derived from the cores. Samples removed from the cores are designated by distance measured in centimeters from the top of the section to the top and bottom of each sample removed from that section. In curated hard-rock sections, sturdy plastic spacers are placed between pieces that did not fit together to protect them from damage in transit and in storage; therefore, the centimeter interval noted for a hard-rock sample has no direct relationship to that sample's depth within the cored interval, but is only a physical reference to the sample's location within the curated core.

A complete identification number for a sample consists of the following information: Leg, Site, Hole, Core Number, Core Type, Section Number, Piece Number (for hard rock), and Interval in centimeters measured from the top of section. For example, a sample identification of "118-732A-5R-3, (Piece 5B, 15–17 cm)" would be interpreted as representing a sample removed from the interval between 15 and 17 cm below the top of Section 3, Core 5 (R designates that this core was taken with the RCB) of Hole 732A during Leg 118, and that this interval fell within Piece 5, Fragment B, of that section.

## Basement Description Conventions

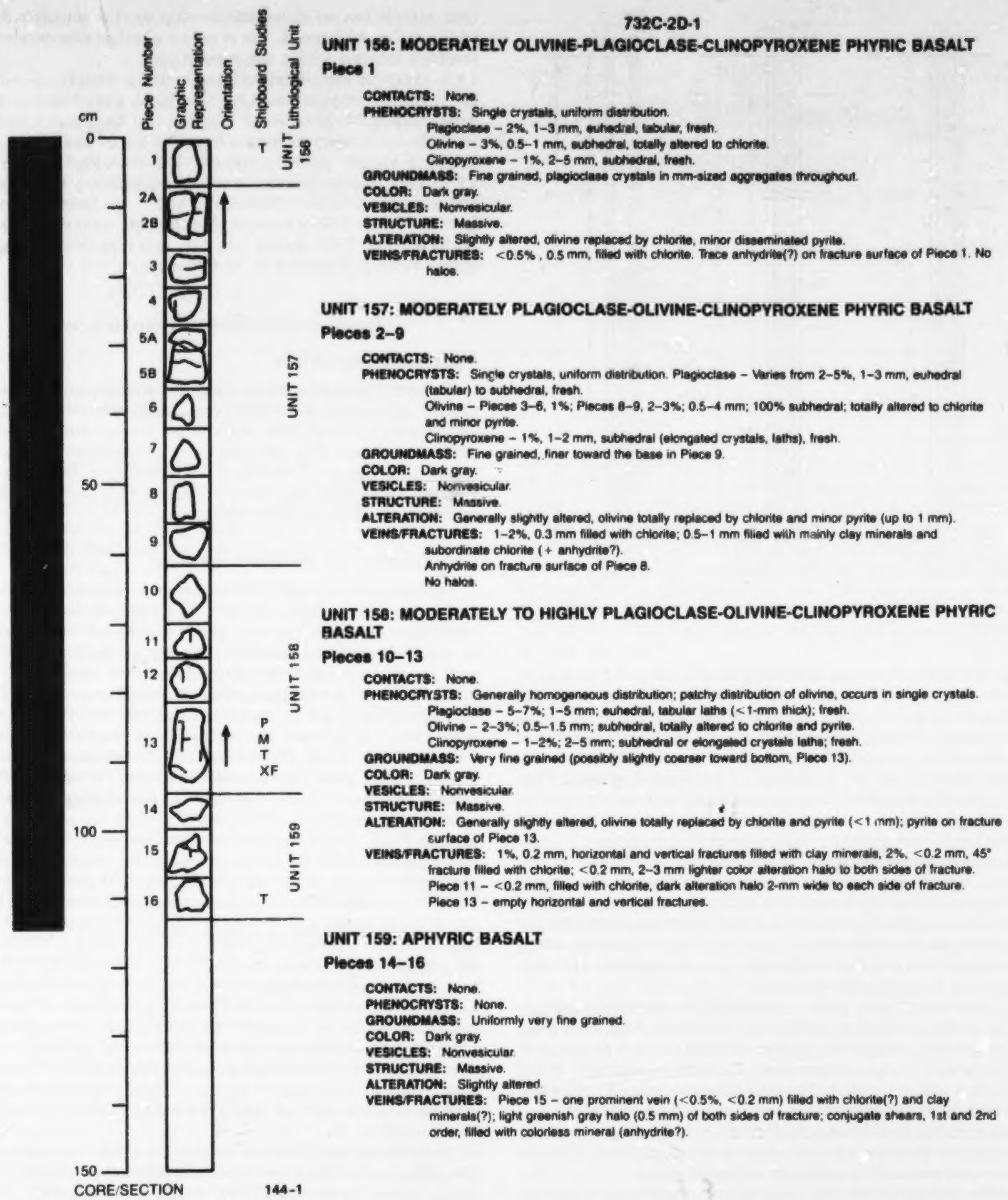
### *Visual Core Descriptions*

Representation of igneous rocks in barrel sheets is too compressed to provide adequate information for potential sampling. Consequently, visual core description forms, modified from those used aboard ship, are used for more complete graphic representation. Copies of the visual core description forms, as well as other prime data collected during Leg 118, are available on microfilm at all three ODP repositories.

### *Core Curation and Shipboard Sampling*

Igneous rocks are split into archive and working halves using a rock saw with a diamond blade. A petrologist decides on the orientation of each cut so as to preserve unique features and/or to expose important structures. The archive half is described, and samples for shipboard and shore-based analyses are removed from the working half. On a typical igneous core description form (Figs. 5 and 6), the left column, entitled "Graphic Representation," is a visual representation of the archive half. A horizontal line across the entire width of the column denotes plastic spacers glued between rock pieces inside the liner. Each piece is numbered sequentially from the top of each section, beginning with number 1. Pieces are labeled on the rounded, unsawn surface. Pieces that can be fitted together (reassembled like a jigsaw puzzle) are assigned the same number, but are lettered consecutively (e.g., 1A, 1B, 1C, etc.). Spacers are placed between pieces of different numbers, but not between those having different letters and the same number. Presence of a spacer may represent a substantial interval of no recovery. Whenever the original unsplit piece was sufficiently large that it could not have rotated top to bottom about a horizontal axis in the liner, an arrow was added to the label pointing to the top of the section. Care was taken to ensure that orientation was not lost during splitting and labeling. Oriented pieces are indicated on the description forms by upward-pointing arrows in the "Orientation" column to the right of the piece. Because pieces are free to turn about a vertical axis during drilling, azimuthal orientation is not possible.

Immediately after the core is split and before the rock is dry, sampling is conducted for shipboard physical properties, magnetics, X-ray fluorescence (XRF), and thin-section studies. Minicores are taken from the working half and stored in seawater for measuring physical properties and magnetics. These minicores are later subdivided for XRF analysis and thin sectioning, which ensures that as many measurements as possible are made on the same pieces of rock. At least one minicore is taken from each lithologic unit when recovery permits. On the visual core description forms, the type of measurement and approximate sample interval are indicated in the column headed "Shipboard Studies," using the following notation:



**732C-2D-1**

**UNIT 156: MODERATELY OLIVINE-PLAGIOCLASE-CLINOPYROXENE PHYRIC BASALT**

**Piece 1**

**CONTACTS:** None.
**PHENOCRYSTS:** Single crystals, uniform distribution.
Plagioclase – 2%, 1–3 mm, euhedral, tabular, fresh.
Olivine – 3%, 0.5–1 mm, subhedral, totally altered to chlorite.
Clinopyroxene – 1%, 2–5 mm, subhedral, fresh.
**GROUNDMASS:** Fine grained, plagioclase crystals in mm-sized aggregates throughout.
**COLOR:** Dark gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Massive.
**ALTERATION:** Slightly altered, olivine replaced by chlorite, minor disseminated pyrite.
**VEINS/FRACTURES:** <0.5% , 0.5 mm, filled with chlorite. Trace anhydrite(?) on fracture surface of Piece 1. No halos.

**UNIT 157: MODERATELY PLAGIOCLASE-OLIVINE-CLINOPYROXENE PHYRIC BASALT**

**Pieces 2–9**

**CONTACTS:** None.
**PHENOCRYSTS:** Single crystals, uniform distribution. Plagioclase – Varies from 2–5%, 1–3 mm, euhedral (tabular) to subhedral, fresh.
Olivine – Pieces 3–6, 1%; Pieces 8–9, 2–3%; 0.5–4 mm; 100% subhedral; totally altered to chlorite and minor pyrite.
Clinopyroxene – 1%, 1–2 mm, subhedral (elongated crystals, laths), fresh.
**GROUNDMASS:** Fine grained, finer toward the base in Piece 9.
**COLOR:** Dark gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Massive.
**ALTERATION:** Generally slightly altered, olivine totally replaced by chlorite and minor pyrite (up to 1 mm).
**VEINS/FRACTURES:** 1–2%, 0.3 mm filled with chlorite; 0.5–1 mm filled with mainly clay minerals and subordinate chlorite (+ anhydrite?).
Anhydrite on fracture surface of Piece 8.
No halos.

**UNIT 158: MODERATELY TO HIGHLY PLAGIOCLASE-OLIVINE-CLINOPYROXENE PHYRIC BASALT**

**Pieces 10–13**

**CONTACTS:** None.
**PHENOCRYSTS:** Generally homogeneous distribution; patchy distribution of olivine, occurs in single crystals.
Plagioclase – 5–7%; 1–5 mm; euhedral, tabular laths (<1-mm thick); fresh.
Olivine – 2–3%; 0.5–1.5 mm; subhedral, totally altered to chlorite and pyrite.
Clinopyroxene – 1–2%; 2–5 mm; subhedral or elongated crystals laths; fresh.
**GROUNDMASS:** Very fine grained (possibly slightly coarser toward bottom, Piece 13).
**COLOR:** Dark gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Massive.
**ALTERATION:** Generally slightly altered, olivine totally replaced by chlorite and pyrite (<1 mm); pyrite on fracture surface of Piece 13.
**VEINS/FRACTURES:** 1%, 0.2 mm, horizontal and vertical fractures filled with clay minerals, 2%, <0.2 mm, 45° fracture filled with chlorite; <0.2 mm, 2–3 mm lighter color alteration halo to both sides of fracture.
Piece 11 – <0.2 mm, filled with chlorite, dark alteration halo 2-mm wide to each side of fracture.
Piece 13 – empty horizontal and vertical fractures.

**UNIT 159: APHYRIC BASALT**

**Pieces 14–16**

**CONTACTS:** None.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Uniformly very fine grained.
**COLOR:** Dark gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Massive.
**ALTERATION:** Slightly altered.
**VEINS/FRACTURES:** Piece 15 – one prominent vein (<0.5%, <0.2 mm) filled with chlorite(?) and clay minerals(?); light greenish gray halo (0.5 mm) of both sides of fracture; conjugate shears, 1st and 2nd order, filled with colorless mineral (anhydrite?).

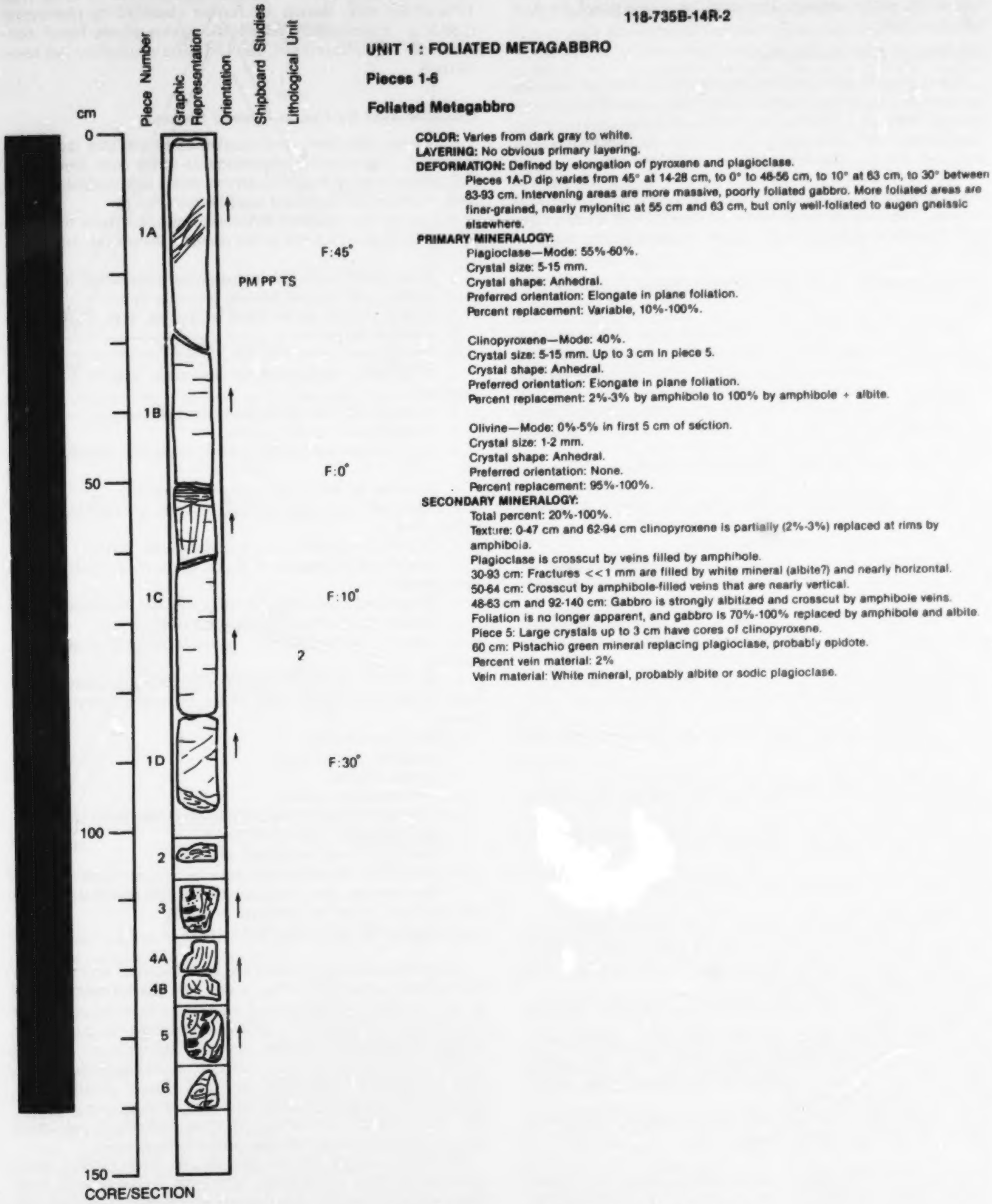
Figure 5. Example of a completed igneous core description (barrel sheet) form for fine- and medium-grained extrusives and dikes.

XRD = X-ray diffraction analysis
XRF = X-ray fluorescence analysis
PM = magnetic measurements
TS = thin section
PP = physical-properties measurements
TC = thermal-conductivity measurements
SEM = scanning-electron-microscope image

Thermal conductivity was measured using pieces of the working half core and required that the sawn surface be polished using carborundum grits.

### *Lithologic Description*

Lithologic descriptions were prepared in a systematic way, ensuring that all important features (e.g., nature of contacts,


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
2
3
4A
4B
5
6
PM PP TS
2
F:45°
F:0°
F:10°
F:30°
CORE/SECTION

**118-735B-14R-2**

**UNIT 1 : FOLIATED METAGABBRO**

**Pieces 1-6**

**Foliated Metagabbro**

**COLOR:** Varies from dark gray to white.
**LAYERING:** No obvious primary layering.
**DEFORMATION:** Defined by elongation of pyroxene and plagioclase.
Pieces 1A-D dip varies from 45° at 14-28 cm, to 0° to 48-56 cm, to 10° at 63 cm, to 30° between 83-93 cm. Intervening areas are more massive, poorly foliated gabbro. More foliated areas are finer-grained, nearly mylonitic at 55 cm and 63 cm, but only well-foliated to augen gneissic elsewhere.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane foliation.
Percent replacement: Variable, 10%-100%.

Clinopyroxene—Mode: 40%.
Crystal size: 5-15 mm. Up to 3 cm in piece 5.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane foliation.
Percent replacement: 2%-3% by amphibole to 100% by amphibole + albite.

Olivine—Mode: 0%-5% in first 5 cm of section.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 95%-100%.
**SECONDARY MINERALOGY:**
Total percent: 20%-100%.
Texture: 0-47 cm and 62-94 cm clinopyroxene is partially (2%-3%) replaced at rims by amphibole.
Plagioclase is crosscut by veins filled by amphibole.
30-93 cm: Fractures <<1 mm are filled by white mineral (albite?) and nearly horizontal.
50-64 cm: Crosscut by amphibole-filled veins that are nearly vertical.
48-63 cm and 92-140 cm: Gabbro is strongly albitized and crosscut by amphibole veins.
Foliation is no longer apparent, and gabbro is 70%-100% replaced by amphibole and albite.
Piece 5: Large crystals up to 3 cm have cores of clinopyroxene.
60 cm: Pistachio green mineral replacing plagioclase, probably epidote.
Percent vein material: 2%
Vein material: White mineral, probably albite or sodic plagioclase.

Figure 6. Example of a completed igneous core description (barrel sheet) form for coarse-grained plutonics.

distribution and percentage of phenocrysts, groundmass texture, color, vesicle content, alteration, etc.) were noted for each unit described.

### *Macroscopic Core Descriptions*

Igneous rocks are classified mainly on the basis of mineralogy and texture. When describing the cores, a checklist of macroscopic features is followed to ensure consistent and complete descriptions. Two such checklists, one for extrusive rocks and dikes and one for plutonic rocks, are presented below.

Two forms are used to describe hard rocks: one for macroscopic description of cores and one for the description of thin sections. The data on these forms go directly into a computerized database that is accessible to the entire scientific community.

### *Checklist Used for Fine- and Medium-Grained Extrusives and Dikes*

Enter leg, site, hole, core number and type, and section information. Draw the graphic representation of the core; number the rock pieces; enter orientation arrows where appropriate; and record positions of shipboard samples (see Fig. 5).

Subdivide the core into lithologic units, using the criteria of changing grain size, occurrence of glassy margins, and changes in petrographic type and phenocryst abundances.

For each lithologic unit, answer the following:

1. Enter UNIT number (consecutive downhole), including piece numbers of top and bottom pieces in unit.
2. ROCK NAME (to be filled in last).
3. CONTACT TYPE (e.g., intrusive; discordant; depositional, etc.). Note the presence of glass and its alteration products (in %), give the azimuth and dip of the contact.
4. PHENOCRYSTS. Determine if homogeneous or heterogeneous distribution; if heterogeneous distribution, note variations. For each phenocryst phase determine:
   a. Abundance (%).
   b. Average size in millimeters.
   c. Shape.
   d. Percentage degree of alteration and replacing phases and their relationships.
   e. Further comments.
   f. Fill in (2.) ROCK NAME (see following text for naming basalts).
5. GROUNDMASS texture. Glassy, microcrystalline, fine-grained (< 1 mm), medium-grained (1-5 mm), or coarse-grained (> 5 mm). Note the relative grain size changes within the unit (e.g., coarsening from Piece 1 to Piece 5).
6. COLOR (dry).
7. VESICLES. Give percentage, size, shape, fillings and their relationships (include percentage of vesicles that are filled by alteration minerals), and distribution. Miaroles: give percentage, size, shape, and distribution.
8. STRUCTURE. Massive, pillow lava, thin flow, breccia, etc., and comments.
9. ALTERATION. Fresh (< 2% alteration), slightly (2%-10%), moderately (10%-40%), highly (40%-80%), very highly (80%-95%), or completely (95%-100%) altered. Type, form, and distribution of alteration.
10. VEINS/FRACTURES. Percentage present, width, orientation, fillings and relationships, halos.

Basalts are termed aphyric, sparsely phyric, moderately phyric, or highly phyric, depending upon the proportion of phenocrysts visible with the hand lens or binocular microscope (approximately 10X). Basalts are called aphyric if phenocrysts clearly amount to less than 1% of the rock, sparsely phyric if phenocryst content ranges from 1%-2%, moderately phyric at 2%-10%, and highly phyric if phenocrysts amount to more than 10% of the rock. Basalts are further classified by phenocryst type (e.g., a moderately plagioclase-olivine phyric basalt contains 2%-10% phenocrysts, most of them plagioclase but some olivine).

### *Checklist Used for Coarse-Grained Plutonics*

Enter leg, site, hole, core number and type, and section information. Draw graphic representation of the core; number the rock pieces; enter orientation arrows where appropriate; and record positions of shipboard samples (see Fig. 6).

Subdivide the core into lithologic units. For each lithologic unit or section, whichever is the smaller, answer the following:

1. Enter UNIT number (consecutive downhole), including piece numbers of top and bottom pieces in unit.
2. ROCK NAME (to be filled in last; see Figs. 7-10).
3. COLOR (dry).
4. LAYERING.
   a. If massive, nonlayered, or isotropic, skip to 5 on this checklist.
   b. Average thickness of different layer types.
   c. Azimuth and dip of layering.
   d. Types of layering (modal, phase, grain size, graded, rhythmic, cyclic).
   e. Sequence of layers and relative abundance.
   f. Layer contacts (sharp, abrupt, smooth, gradational, undulating, rough).
5. DEFORMATION. If rock is deformed, note:
   a. Nature and inclination of faults, folds, shear, and/or brecciated zones.
   b. Nature and inclination of foliations and lineations.
   c. Features that define the foliation or lineation.
   d. Grain size variations due to granulation and/or recrystallization.
6. PRIMARY MINERALOGY. Includes intergranular and granular phases. Note for each phase, in order of modal abundance:
   a. Modal percentage.
   b. Range of crystal sizes.
   c. Crystal shapes.
   d. Preferred orientations.
   e. Percentage replacement with what replacement mineral.
7. SECONDARY MINERALOGY
   a. Total percentage secondary phases.
   b. Textures of secondary phases.
   c. Vein material, note total percentage vein material, average vein thickness, types and textures of filling.
8. Note ADDITIONAL FEATURES.

Whenever possible, peridotites are classified according to their primary mineralogy (Figs. 9 and 10). If no primary minerals can be identified because of extensive serpentinization, the serpentinized peridotites are called serpentinites. In the case of partially serpentinized samples, the term "serpentinized" is used to modify the rock name (e.g., "serpentinized harzburgite"). In some serpentinites, serpentine minerals closely pseudomorph primary minerals (e.g., lizardite replacing orthopyroxene in bastite). The primary mineralogy of these samples is estimated from the abundances of various pseudomorph types.

Describers on Leg 118 operated in two teams (shifts), each consisting of four petrologists. Interteam meetings were held frequently to ensure that descriptions were prepared consistently during both shifts and that all petrologists agreed upon the division of recovered core into lithologic units.

Once the lithologic description had been agreed upon by the shipboard scientific party, the final core description was assem-

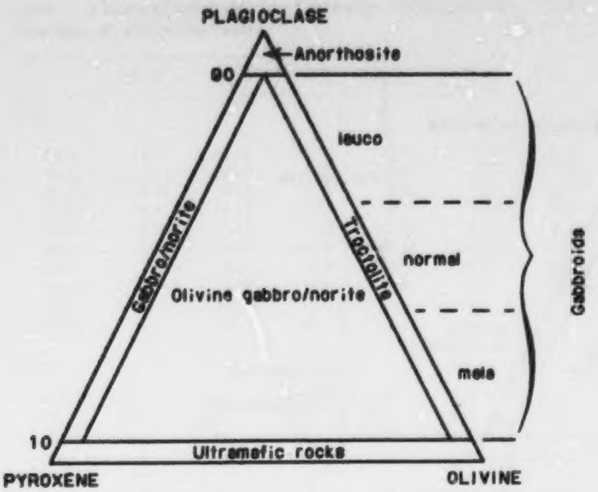


Figure 7. Classification of gabbroic rocks composed of plagioclase, pyroxene, and olivine (after Streckeisen, 1974).

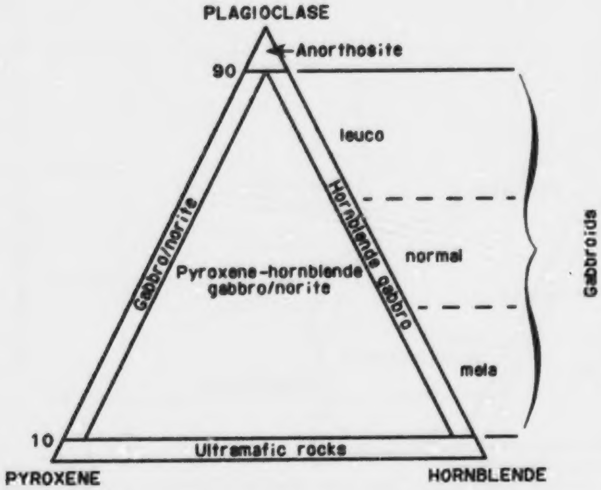


Figure 8. Classification of gabbroic rocks containing hornblende (after Streckeisen, 1974).

bled on an igneous barrel sheet (Figs. 5 and 6). These barrel sheets are published in this volume.

### *Thin-Section Description*

Thin-section billets of basement rocks recovered during Leg 118 were examined (1) to help define unit boundaries indicated by hand-specimen core descriptions, (2) to confirm the identity of the petrographic groups represented in the cores, and (3) to define their secondary alteration mineralogy. At least one thin section was made of each unit identified in hand specimen where sufficient rock was available.

The rationale for the assignment of unit boundaries, based on modal mineralogy and chemistry, is presented in the "Lithostratigraphy" section, Site 735 chapter (this volume). Percentages of individual mineral phases were estimated visually and are reported on the detailed thin-section description sheets (available on microfilm at the repositories). Modal abundances determined by point counting are reported in the "Petrography" section of each site chapter. For the thin-section modal estimates, we decided to include porphyroclasts with primary minerals and neoblasts with secondary minerals. The terms sparsely, moderately, and highly abundant are used in the same manner as for hand-specimen descriptions. In cases where discrepancies arise over the composition and abundance of mineral phases between hand-specimen and thin-section analyses, thin-section discriptions are used in the "Lithostratigraphy" section, Site 735 chapter (this volume).

### *Basement Alteration*

Alteration effects from seawater interaction with igneous rocks were described in hand specimens and thin sections. The width and color of any alteration halos around fractures or vugs were noted in the core descriptions. The identities of secondary minerals filling fractures, vesicles, and replacing igneous phases were estimated in core descriptions and refined in thin sections, which were augmented in some cases by X-ray diffraction (XRD) and later electron microprobe analyses performed using shipboard thin sections. The total percentages of the various secondary minerals were also estimated from thin-section examinations.

## X-Ray Diffraction Analyses

A Phillips ADP 3520 X-ray diffractometer was used for the XRD analyses of unknown secondary mineral phases. Instrument conditions were as follows:

$CuK\alpha$ radiation with nickel filter
40 kV 35 mA
Goniometer scan from 2° to 70° $2\theta$
Step size 0.02°
Count time 1 s

Since only bulk mineralogy was required, the samples were ground using the Spex 8000 Mixer Mill or, when there was very little sample material, using the agate mortar and pestle. The material was then pressed into the sample holders for X-ray analysis.

Resulting diffractograms were interpreted with the help of a computerized search and match routine using Joint Committee on Powder Diffraction Standards (JCPDS) powder files and tabulated data for clay minerals in Brindley and Brown (1980).

## X-Ray Fluorescence Analyses

During Leg 118, the completely automated, wavelength-dispersive XRF system ARL 8420, available on board the *JOIDES Resolution*, was used to determine the major oxide compositions and trace element abundances of whole-rock samples.

Analyses of the major oxides were performed on lithium borate glass disks doped with lanthanum as a "heavy absorber." The technique is basically that developed by Norrish and Hutton (1969), with some minor modifications: 500 mg of rock powder that had been ignited for 2 hr at about 1030°C was mixed with 6.0 g of dry flux consisting of 80% lithium tetraborate and 20% $La_2O_3$. This mixture was then melted at 1150°C in a platinum-gold crucible for about 10 minutes and poured into a platinum-gold mold using a Claisse Fluxer. The 12:1 flux-to-sample ratio chosen was found sufficient to eliminate matrix effects over a certain range of rock compositions in such a manner that the following linear relationship between X-ray intensity and concentration holds:

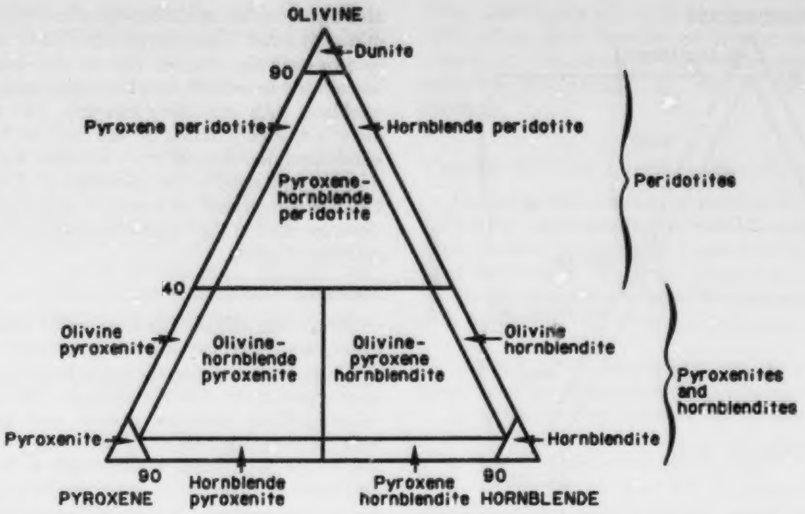

OLIVINE
Dunite
90
Pyroxene peridotite
Hornblende peridotite
Pyroxene-hornblende peridotite
Peridotites
40
Olivine pyroxenite
Olivine-hornblende pyroxenite
Olivine-pyroxene hornblendite
Olivine hornblendite
Pyroxenites and hornblendites
Pyroxenite
Hornblendite
90
PYROXENE
Hornblende pyroxenite
Pyroxene hornblendite
90
HORNBLENDE

Figure 9. Classification of ultramafic rocks that contain hornblende (after Streckeisen, 1974).

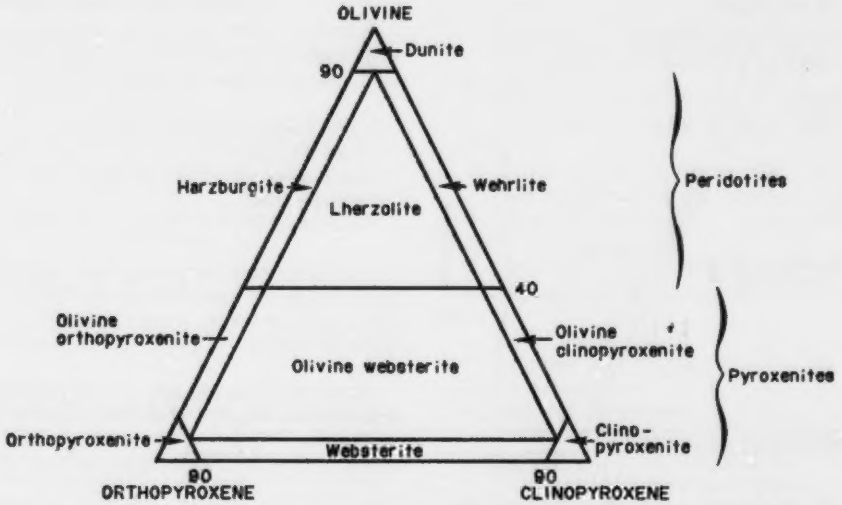

OLIVINE
Dunite
90
Harzburgite
Lherzolite
Wehrlite
Peridotites
40
Olivine orthopyroxenite
Olivine websterite
Olivine clinopyroxenite
Pyroxenites
Orthopyroxenite
Websterite
Clino-pyroxenite
90
ORTHOPYROXENE
90
CLINOPYROXENE

Figure 10. Classification of ultramafic rocks composed of olivine, orthopyroxene, and clinopyroxene (after Streckeisen, 1974).

$$C_i = (I_i \times m_i) - b_i,$$

where

$C_i$ = concentration of oxide $i$ (wt%),
$I_i$ = net peak X-ray intensity of oxide $i$,
$m_i$ = slope of calibration curve for oxide $i$ (wt%/cps),
$b_i$ = apparent background concentration for oxide $i$ (wt%).

The slope $m_i$ was calculated from a calibration curve derived from the measurement of a set of well-analyzed "standards" (reference rocks). The background $b_i$ was determined either on blanks or derived mathematically from the calibration curves.

Because we anticipated recovery of two chemically distinct rock groups, namely basaltic/gabbroic and ultramafic, whose matrix differences are too large to be completely overcome by the heavy absorber/dilution method applied, we set up separate calibration curves for each of these groups. For calibration of basaltic rocks, the reference samples BHVO, AII-92, K 1919, NBS 688, DR-N, AGV, and GH were used. The calibration curves for ultramafic samples are based on the reference rocks PCC, DTS, UB-N, JP-1, NIM-D, and MUN (from Munster Univ., Federal Republic of Germany), and on BR and BHVO, where appropriate.

As a result of the sample preparation procedure chosen, the actual chemical composition of these rocks had to be recalculated to a water-free and $CO_2$-free basis, with all iron as $Fe_2O_3$ and normalized to sum = 100%. When summing up, we also included the nickel and chromium contents (as oxides) because these elements constitute about 0.5 wt% of the ultramafic rocks. Table 1 presents the values used for calibration of ultramafic rocks. The silicon, magnesium, calcium, and aluminum calibration curves for ultramafic rocks are shown in Figures 11 and 12.

The XRF working conditions used are listed in Table 2. Systematic errors due to short-term or long-term fluctuations in X-

**Table 1. Chemical composition of reference rocks used for calibration lines of ultramafic rocks.**

| | UB-N | JP-1 | NIM-D | MUN | DTS | PCC |
|---|---|---|---|---|---|---|
| wt% | | | | | | |
| $SiO_2$ | 44.78 | 43.48 | 38.56 | 41.90 | 40.50 | 43.85 |
| $TiO_2$ | 0.12 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 |
| $Al_2O_3$ | 3.29 | 0.64 | 0.30 | 0.40 | 0.24 | 0.77 |
| $Fe_2O_3$ | 9.47 | 8.55 | 16.80 | 7.37 | 8.64 | 8.74 |
| MnO | 0.14 | 0.13 | 0.22 | 0.10 | 0.11 | 0.12 |
| MgO | 39.98 | 45.84 | 43.08 | 49.48 | 49.80 | 45.19 |
| CaO | 1.36 | 0.57 | 0.28 | 0.05 | 0.15 | 0.53 |
| $Na_2O$ | 0.11 | 0.02 | 0.04 | 0.05 | 0.0 | 0.01 |
| $K_2O$ | — | — | — | — | — | — |
| $P_2O_5$ | — | — | — | — | — | — |
| ppm | | | | | | |
| Cr | 2612 | 3046 | 2872 | 2340 | 4000 | 2920 |
| Ni | 2271 | 2523 | 2030 | 2430 | 2269 | 2448 |
| Zn | 92 | 30 | 90 | 36 | 45 | 36 |
| Zr | 8 | 6 | 20 | 15 | <10 | <7 |
| Y | 11 | 1 | nd | 2 | <0.5 | nd |
| Sr | 10 | <1 | 3 | 5 | <1 | <1 |
| Rb | 6 | <1 | nd | 1 | <1 | <1 |

MUN = periodite reference rock, Univ. of Munster, Federal Republic of Germany.

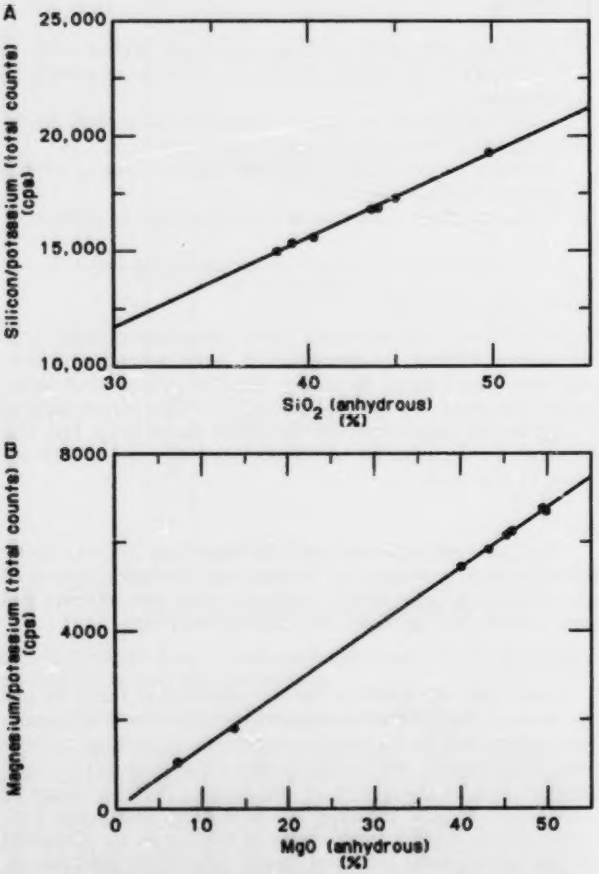


Figure 11. XRF calibration lines of silicon (A) and magnesium (B) in ultramafic rocks. Calibration line shown is the least-squares fit. See Table 1 for the composition of the reference rocks.

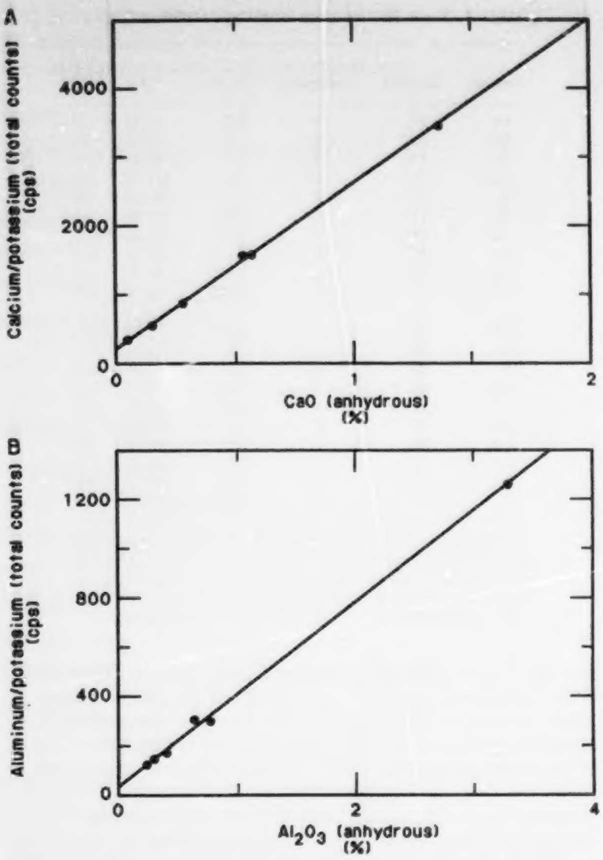


Figure 12. XRF calibration lines of calcium (A) and aluminum (B) in ultramafic rocks. Calibration line shown is the least-squares fit. See Table 1 for the composition of the reference rocks.

ray tube intensity were corrected by normalizing the measured intensities of the samples to that of a standard that was always run together with a set of six samples. To reduce preparation errors, especially weighing errors, two glass disks were prepared for each sample. Standard deviations (in rel %) and detection limits (in wt%) that apply to rocks of basaltic composition are listed in Table 3.

Trace-element determinations were performed on pressed-powder pellets prepared by pressing (with 7 tons of pressure) a mixture of 5.000 g of dry rock powder (dried at 110°C for >2 hr) and 30 drops of polyvinylalcohol binder into an aluminium cap. A modified Compton scattering technique based on the intensity of the rhodium Compton peak was used for matrix absorption corrections (Reynolds, 1967). A comprehensive description of the analytical procedure and the program developed is given in the "Introduction and Explanatory Notes," *Proc. ODP, Init. Repts.*, 111 (Shipboard Scientific Party, 1988a) and need not be repeated here as we adopted this method without modifications.

## Description of Sediments and Sedimentary Rocks

### *Introduction*

The sediment classification system used for Leg 118 is a modified version of that devised by the former JOIDES Panel on Sedimentary Petrology and Physical Properties and adopted

**Table 2. X-ray fluorescence working conditions.**

| Element | Detector | Collimator | Crystal | 2θ | CT (s) |
|---|---|---|---|---|---|
| Fe | FC | F | LiF | 57.52 | 40 |
| Mn | KrC | F | LiF | 62.98 | 40 |
| Ti | FC | F | LiF | 86.14 | 40 |
| Ca | FC | C | LiF | 113.16 | 40 |
| K | FC | F | LiF | 136.65 | 40 |
| Si | FC | C | PET | 109.25 | 40 |
| Al | FC | C | PET | 145.27 | 100 |
| P | FC | C | Ge | 140.94 | 200 |
| Mg | FC | C | T1AP | 44.87 | 200 |
| Na | FC | C | T1AP | 54.71 | 200 |
| Nb | SC | F | LiF | 21.37 | 200 |
| Zr | SC | F | LiF | 21.53 | 100 |
| Y | SC | F | LiF | 23.78 | 100 |
| Sr | SC | F | LiF | 25.13 | 100 |
| Rb | SC | F | LiF | 26.60 | 100 |
| Zn | SC | F | LiF | 41.79 | 60 |
| Cu | SC | F | LiF | 45.02 | 60 |
| Ni | SC | C | LiF | 48.67 | 60 |
| Cr | FC | F | LiF | 69.35 | 60 |
| V | FC | F | LiF* | 122.84 | 60 |

All elements measured on K-alpha line, using a rhodium x-ray tube operated at 60 kV and 50 mA: SC = NaI scintillation counter; FC = flow proportional counter (P10 gas); KrC = sealed krypton gas counter; Collimator: F = fine; C = coarse; LiF = LiF (200); LiF* = LiF (220); CT = counting time.

**Table 3. Analytical errors and detection limits of oxide and trace elements.**

| | Analytical error (rel%) | Detection limit (wt% or ppm) |
|---|---|---|
| $SiO_2$ | 0.30 | 0.03 |
| $TiO_2$ | 0.37 | 0.01 |
| $Al_2O_3$ | 0.40 | 0.01 |
| $Fe_2O_3$ | 0.20 | 0.01 |
| MnO | 0.10 | 0.005 |
| MgO | 0.60 | 0.01 |
| CaO | 0.30 | 0.005 |
| $Na_2O$ | 3.8 | 0.03 |
| $K_2O$ | 0.10 | 0.01 |
| $P_2O_5$ | 0.10 | 0.01 |
| Nb | 0.2 | 0.5 |
| Zr | 0.5 | 0.6 |
| Y | 1.0 | 0.6 |
| Sr | 0.3 | 0.6 |
| Rb | 3.6 | 0.6 |
| Zn | 1.0 | 1.0 |
| Cu | 1.5 | 1.2 |
| Ni | 0.6 | 1.2 |
| Cr | 1.3 | 2.0 |
| V | 2.0 | 3.0 |

for use by the JOIDES Planning Committee in March 1974. This classification scheme was designed to adhere closely to ODP standards and to describe the nature of the sediments recovered during Leg 118. The classification is descriptive (based on sediment properties) rather than generic, and often tends to make the divisions between sedimentary categories artificial. Sediment and rock names were defined solely on the basis of composition and texture. These data were primarily determined on board ship by (1) microscopic observation of smear slides and thin sections, (2) visual observation of cores using a hand lens and binocular microscope, and (3) unaided visual observation. Calcium carbonate content was estimated in smear slides. Other geologic features determined were color, sedimentary structures, and firmness.

### *Sediment Classification Parameters*

#### *Induration*

The criteria used to determine the induration of calcareous deposits found during Leg 118 are those of Gealy et al. (1971). For all other deposits, subjective estimates of induration are based on the behavior of the deposits during the core-cutting procedure. There are three classes of calcareous sediments: (1) soft—oozes with little strength that are readily deformed under the finger or the broad blade of a spatula; (2) firm—chalks that are partly indurated oozes or friable limestones, readily deformed under the fingernail or the edge of a spatula blade; and (3) hard—restricted to limestones as a term for cemented rocks. Noncalcareous sediments are divided into two classes of induration: (1) if the material is at such a low state of induration as to allow the core to be split with a wire cutter, the sediment name only is used (e.g., silty clay, mud); and (2) if the core must be cut on the bandsaw or diamond saw, the suffix "stone" is used (e.g., silty claystone, mudstone, or shale, if fissile).

#### *Drilling Disturbance*

Recovered rocks and sediments may be slightly to extremely disturbed from coring and drilling. Five types of disturbance categories were used (Fig. 13) for consideration when completing the core description barrel sheets under the column entitled "Drilling Disturbance." The disturbance categories are defined as follows.

1. Slightly deformed, bedding contacts are slightly bent.
2. Moderately deformed, bedding contacts have undergone extreme bowing.
3. Very deformed, bedding is completely disturbed, sometimes showing symmetrical diapirlike structure.
4. Soupy, water-saturated intervals that have lost all aspects of original bedding.
5. Breccia, firm sediments or rocks fractured by drilling.

Lithified sediments were not recovered during Leg 118.

#### *Sedimentary Structures*

In soft and even in some harder sedimentary cores, it is sometimes difficult to distinguish between natural structures and structures created by coring. However, where such structures were observed, they are entered into the column entitled "Sedimentary Structures" on the barrel sheets (Fig. 14). The symbols for sedimentary structures used during Leg 118 are given in Figure 13.

#### *Color*

The color of recovered material from Leg 118 was determined according to standard Munsell and Geological Society of America Rock Color charts while the cores were still wet and was recorded on the visual core description forms.

#### *Lithology*

Lithologies are shown in the core description forms by one or more of the symbols shown in Figure 15. These lithologies were determined by the relative abundances of calcium carbonate, biogenic opal, and authigenic and terrigenous detrital components and by the degree of induration. The percentage of abundances of these components was routinely determined from smear slides. Relative proportions of lithologies are simplified on the barrel sheets; thus, one should refer to the sediment descriptions on the visual core description forms (available through the ODP Database Group) and smear-slide data for more detailed lithologic information. The locations of all smear-slide samples taken for analysis were indicated in the column marked

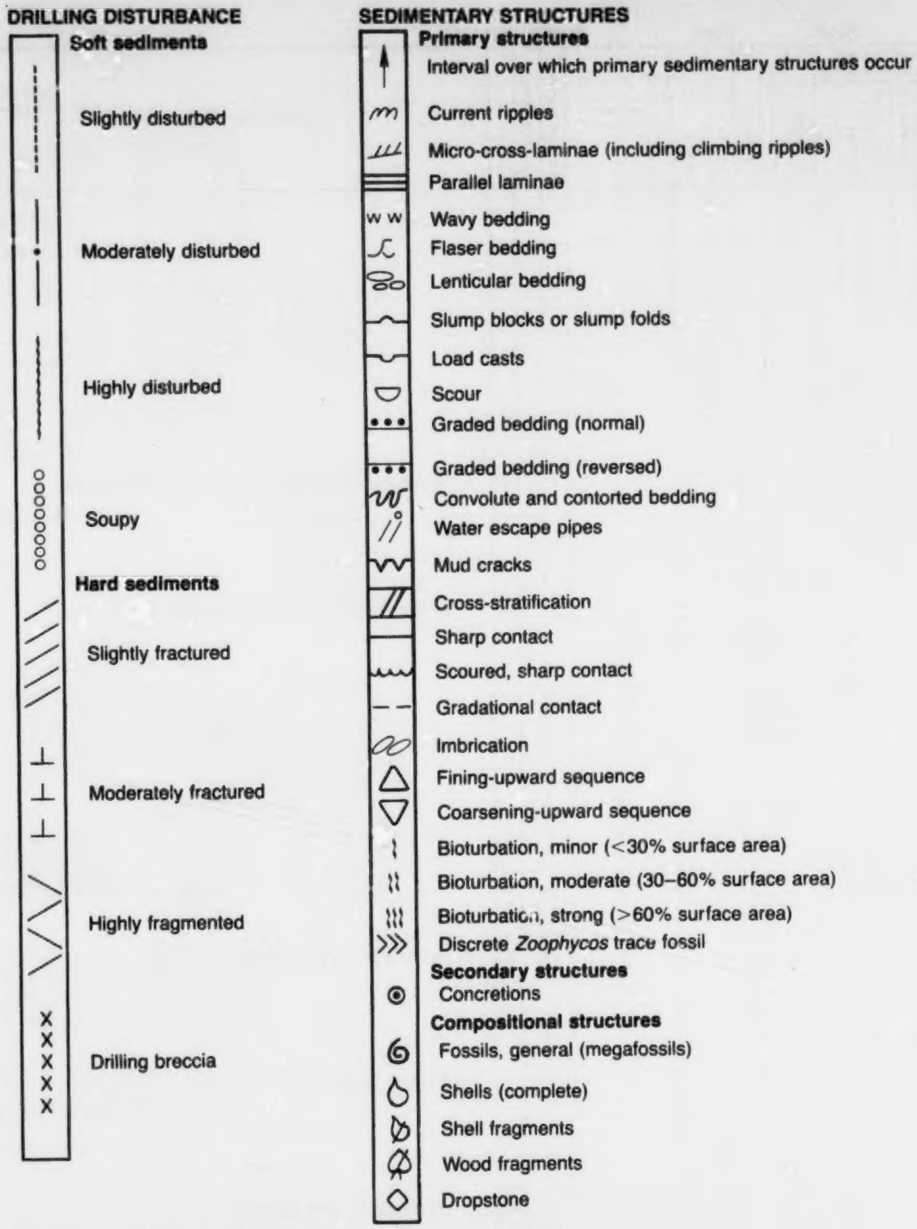

DRILLING DISTURBANCE
Soft sediments
Slightly disturbed
Moderately disturbed
Highly disturbed
Soupy
Hard sediments
Slightly fractured
Moderately fractured
Highly fragmented
Drilling breccia
SEDIMENTARY STRUCTURES
Primary structures
Interval over which primary sedimentary structures occur
Current ripples
Micro-cross-laminae (including climbing ripples)
Parallel laminae
Wavy bedding
Flaser bedding
Lenticular bedding
Slump blocks or slump folds
Load casts
Scour
Graded bedding (normal)
Graded bedding (reversed)
Convolute and contorted bedding
Water escape pipes
Mud cracks
Cross-stratification
Sharp contact
Scoured, sharp contact
Gradational contact
Imbrication
Fining-upward sequence
Coarsening-upward sequence
Bioturbation, minor (<30% surface area)
Bioturbation, moderate (30–60% surface area)
Bioturbation, strong (>60% surface area)
Discrete Zoophycos trace fossil
Secondary structures
Concretions
Compositional structures
Fossils, general (megafossils)
Shells (complete)
Shell fragments
Wood fragments
Dropstone

Figure 13. Sedimentary deformation and structure symbol codes.

"Samples" on the barrel sheets, and the results of the analyses are listed below the core descriptions.

### Sedimentary Description Conventions

A summary of the lithologic classification scheme adopted by ODP at the time of Leg 118 is shown in Figure 16. The major component of a sediment type is always listed last in the sediment name, whereas qualifiers are used as long as the components are present with greater than 10% abundance in smear slides. The least abundant qualifier is always listed first. As many qualifiers as necessary to adequately describe the sediments were used. Common qualifiers used include clay, radiolarian, diatom, sponge, foraminifer, and calcareous nannofossil.

#### *Pelagic Clay*

Pelagic clay is principally composed of authigenic pelagic material that accumulated at very slow rates. The boundary of pelagic clay with terrigenous sediments is where authigenic components (iron-manganese micronodules, zeolites), fish debris, etc., become common (more than 10% in smear slides). The boundary of pelagic clay with siliceous biogenic sediments is the point at which there is less than 30% identifiable siliceous remains. No pelagic clay was recovered during Leg 118.

#### *Siliceous Biogenic Sediments*

Siliceous biogenic sediments are distinguished from pelagic clay because they contain common (more than 30% in smear

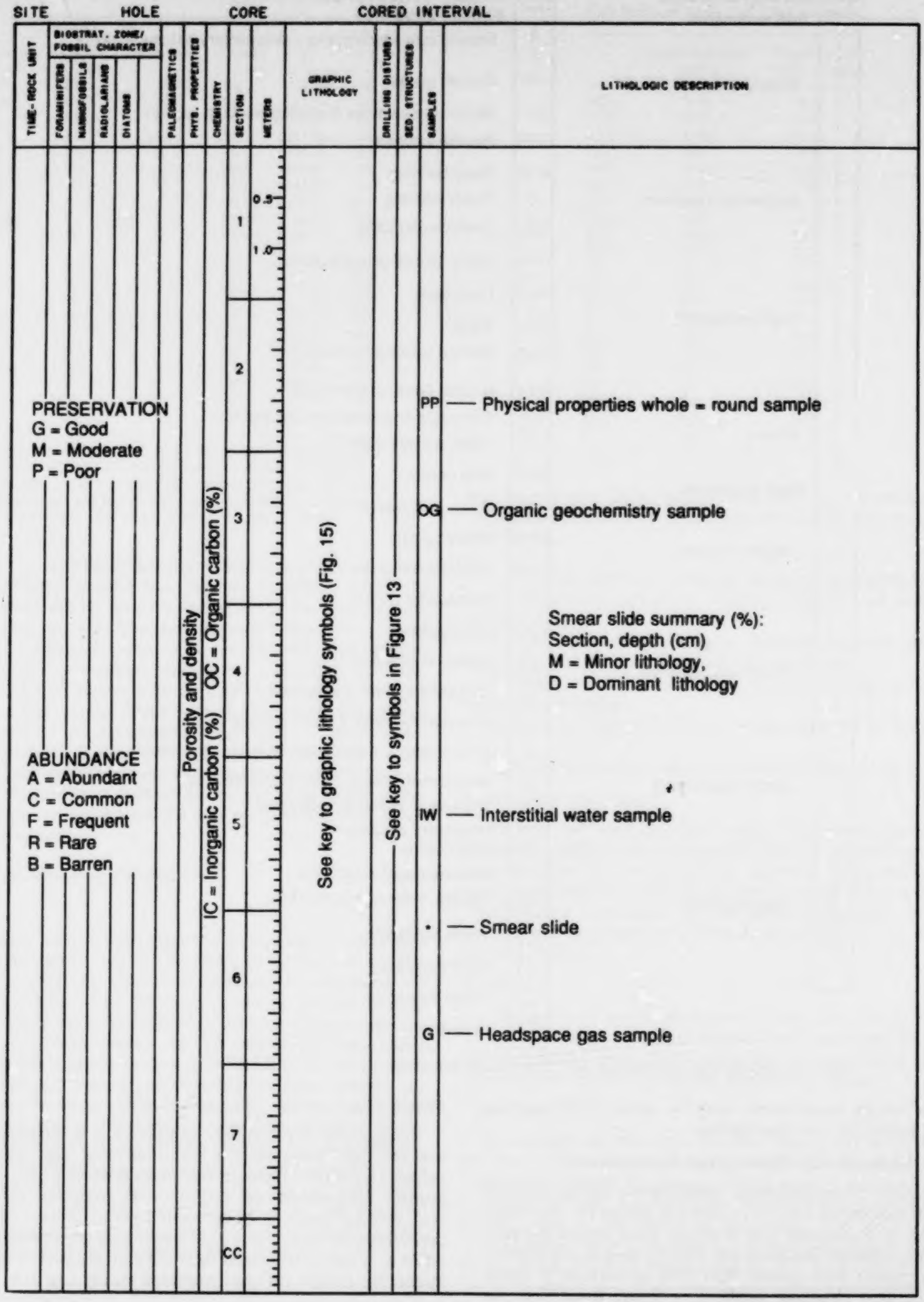

SITE
HOLE
CORE
CORED INTERVAL
TIME-ROCK UNIT
BIOSTRAT. ZONE/FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
PALEOMAGNETICS
PHYS. PROPERTIES
CHEMISTRY
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURB.
SED. STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
4
5
6
7
CC
PRESERVATION
G = Good
M = Moderate
P = Poor
ABUNDANCE
A = Abundant
C = Common
F = Frequent
R = Rare
B = Barren
Porosity and density
IC = Inorganic carbon (%) OC = Organic carbon (%)
See key to graphic lithology symbols (Fig. 15)
See key to symbols in Figure 13
PP — Physical properties whole = round sample
OG — Organic geochemistry sample
Smear slide summary (%):
Section, depth (cm)
M = Minor lithology,
D = Dominant lithology
IW — Interstitial water sample
• — Smear slide
G — Headspace gas sample

Figure 14. Barrel sheet form for sediments/sedimentary rocks.

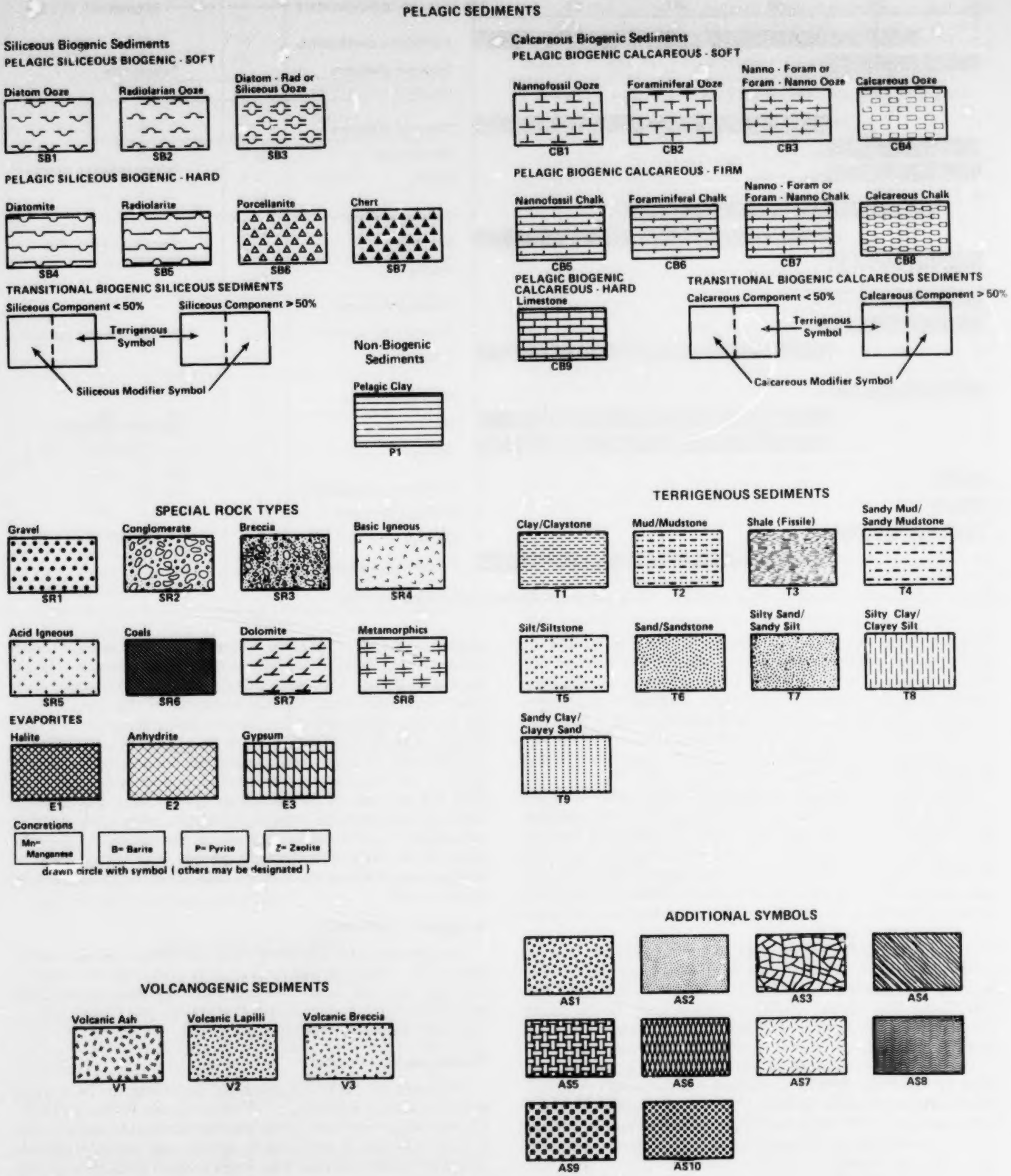

PELAGIC SEDIMENTS
Siliceous Biogenic Sediments
PELAGIC SILICEOUS BIOGENIC - SOFT
Diatom Ooze
SB1
Radiolarian Ooze
SB2
Diatom - Rad or Siliceous Ooze
SB3
PELAGIC SILICEOUS BIOGENIC - HARD
Diatomite
SB4
Radiolarite
SB5
Porcellanite
SB6
Chert
SB7
TRANSITIONAL BIOGENIC SILICEOUS SEDIMENTS
Siliceous Component < 50%
Siliceous Component > 50%
Terrigenous Symbol
Siliceous Modifier Symbol
Non-Biogenic Sediments
Pelagic Clay
P1
Calcareous Biogenic Sediments
PELAGIC BIOGENIC CALCAREOUS - SOFT
Nannofossil Ooze
CB1
Foraminiferal Ooze
CB2
Nanno - Foram or Foram - Nanno Ooze
CB3
Calcareous Ooze
CB4
PELAGIC BIOGENIC CALCAREOUS - FIRM
Nannofossil Chalk
CB5
Foraminiferal Chalk
CB6
Nanno - Foram or Foram - Nanno Chalk
CB7
Calcareous Chalk
CB8
PELAGIC BIOGENIC CALCAREOUS - HARD
Limestone
CB9
TRANSITIONAL BIOGENIC CALCAREOUS SEDIMENTS
Calcareous Component < 50%
Calcareous Component > 50%
Terrigenous Symbol
Calcareous Modifier Symbol
SPECIAL ROCK TYPES
Gravel
SR1
Conglomerate
SR2
Breccia
SR3
Basic Igneous
SR4
Acid Igneous
SR5
Coals
SR6
Dolomite
SR7
Metamorphics
SR8
EVAPORITES
Halite
E1
Anhydrite
E2
Gypsum
E3
Concretions
Mn= Manganese
B= Barite
P= Pyrite
Z= Zeolite
drawn circle with symbol ( others may be designated )
TERRIGENOUS SEDIMENTS
Clay/Claystone
T1
Mud/Mudstone
T2
Shale (Fissile)
T3
Sandy Mud/ Sandy Mudstone
T4
Silt/Siltstone
T5
Sand/Sandstone
T6
Silty Sand/ Sandy Silt
T7
Silty Clay/ Clayey Silt
T8
Sandy Clay/ Clayey Sand
T9
VOLCANOGENIC SEDIMENTS
Volcanic Ash
V1
Volcanic Lapilli
V2
Volcanic Breccia
V3
ADDITIONAL SYMBOLS
AS1
AS2
AS3
AS4
AS5
AS6
AS7
AS8
AS9
AS10

Figure 15. Graphic symbols corresponding to the barrel sheets for sediments and sedimentary rocks.

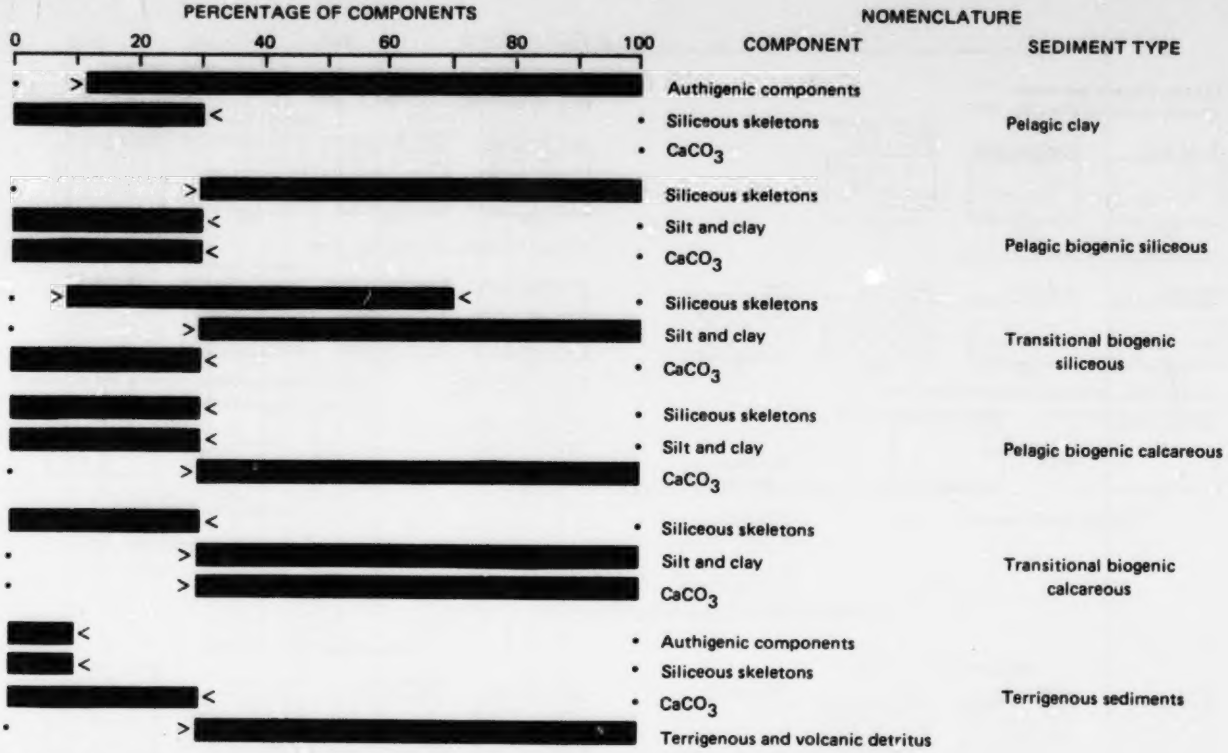


Figure 16. Summary chart of lithologic classification for oceanic sediments used during Leg 118.

slides) siliceous microfossils. Siliceous biogenic sediments are distinguished from the calcareous category by a calcium carbonate content of less than 30%. There are two categories of siliceous biogenic sediments: (1) pelagic siliceous biogenic sediments that contain greater than 30% siliceous microfossils and less than 30% silt and clay, and (2) transitional siliceous biogenic sediments that contain between 10% and 70% siliceous microfossils and greater than 30% silt and clay.

When only one siliceous component exceeds 10%, this component is used to describe the major category of the sediment and is listed last in the sediment name. If more than one siliceous component is in excess of 10%, these qualifiers are listed in order of increasing abundance. If no single siliceous component exceeds 10% but all together total more than 30% (and are present in greater quantities than calcium carbonate), the qualifier siliceous is used.

When pelagic siliceous biogenic sediments are soft, they are called oozes, such as radiolarian or diatom ooze. When sediments of this type are hard, they are called radiolarite or diatomite, depending on the dominant component. If the major component is unspecified, the sediments are called siliceous ooze, porcellanite, or chert, depending on their hardness.

In the transitional biogenic siliceous category, silt and clay make up more than 30% of the sediment, whereas siliceous skeletons make up between 10% and 70% of the sediment. These sediments are called siliceous muds, siliceous mudstones, or muddy siliceous oozes. Where the siliceous component exceeds 50%, the term muddy is used as a qualifier.

### *Calcareous Biogenic Sediment*

Calcareous biogenic sediment is distinguished by a biogenic calcium carbonate content in excess of 30%. There are two classes: (1) pelagic calcareous biogenic sediments and (2) transitional calcareous biogenic sediments, which were not encountered during Leg 118. Soft pelagic biogenic calcareous sediments are called oozes, whereas sediments of this category that are firm are called chalk. Transitional biogenic calcareous sediments are those that contain more than 30% silt and clay.

Qualifiers are used when components are present in excess of 10%. If no calcareous component is present with more than 10% but the sum of all calcareous components exceeds 30% (and is greater than the biogenic silica component), the qualifier calcareous is used to define the major component of the sediment. If no siliceous component exceeds 10% but the total of all siliceous components exceeds 10%, then the qualifier siliceous is used.

### *Terrigenous Sediments*

Terrigenous sediments are divided into textural groups on the basis of the relative proportions of three grain-size constituents, i.e., clay, silt, and sand. The size limits for these constituents are those defined by Wentworth (1922) (Fig. 17). No terrigenous sediments were recovered during Leg 118.

### *Volcanogenic Sediments*

Volcanogenic rocks are described according to the textural and compositional scheme of Wentworth and Williams (1932). The textural groups are (1) volcanic breccia (greater than 32 mm in size), (2) volcanic lapilli (4–32 mm in size), and (3) volcanic ash, tuff if indurated (less than 4 mm in size). Qualifiers for volcanic sediments apply the same way as in terrigenous sediments, where possible noting the dominant composition of the grains. During Leg 118, the category "volcanic breccia" was extended to include sand and gravel of which more than 90% of the grains were of volcanic origin.

| MILLIMETERS | | µm | PHI (Φ) | WENTWORTH SIZE CLASS | |
|---|---|---|---|---|---|
| | | | -20 | | |
| | 4096 | | -12 | Boulder (-8 to -12 Φ) | |
| | 1024 | | -10 | | |
| | 256 | | -8 | Cobble (-6 to -8 Φ) | |
| | 64 | | -6 | | GRAVEL |
| | 16 | | -4 | Pebble (-2 to -6 Φ) | |
| | 4 | | -2 | | |
| | 3.36 | | -1.75 | | |
| | 2.83 | | -1.5 | Granule | |
| | 2.38 | | -1.25 | | |
| | 2.00 | | -1.0 | | |
| | 1.68 | | -0.75 | | |
| | 1.41 | | -0.5 | Very coarse sand | |
| | 1.19 | | -0.25 | | |
| | 1.00 | | 0.0 | | |
| | 0.84 | | 0.25 | | |
| | 0.71 | | 0.5 | Coarse sand | |
| | 0.59 | | 0.75 | | |
| 1/2 | 0.50 | 500 | 1.0 | | |
| | 0.42 | 420 | 1.25 | | |
| | 0.35 | 350 | 1.5 | Medium sand | SAND |
| | 0.30 | 300 | 1.75 | | |
| 1/4 | 0.25 | 250 | 2.0 | | |
| | 0.210 | 210 | 2.25 | | |
| | 0.177 | 177 | 2.5 | Fine sand | |
| | 0.149 | 149 | 2.75 | | |
| 1/8 | 0.125 | 125 | 3.0 | | |
| | 0.105 | 105 | 3.25 | | |
| | 0.088 | 88 | 3.5 | Very fine sand | |
| | 0.074 | 74 | 3.75 | | |
| 1/16 | 0.0625 | 63 | 4.0 | | |
| | 0.053 | 53 | 4.25 | | |
| | 0.044 | 44 | 4.5 | Coarse silt | |
| | 0.037 | 37 | 4.75 | | |
| 1/32 | 0.031 | 31 | 5.0 | | |
| 1/64 | 0.0156 | 15.6 | 6.0 | Medium silt | |
| 1/128 | 0.0078 | 7.8 | 7.0 | Fine silt<br>Very fine silt | |
| 1/256 | 0.0039 | 3.9 | 8.0 | | MUD |
| | 0.0020 | 2.0 | 9.0 | | |
| | 0.00098 | 0.98 | 10.0 | Clay | |
| | 0.00049 | 0.49 | 11.0 | | |
| | 0.00024 | 0.24 | 12.0 | | |
| | 0.00012 | 0.12 | 13.0 | | |
| | 0.00006 | 0.06 | 14.0 | | |

Figure 17. Wentworth size scale (1922).

## BIOSTRATIGRAPHY

### Calcareous Nannofossils

The calcareous nannofossil zonation of Martini (1971) was used during Leg 118. The latest Miocene through Pleistocene marker species used in the zonal scheme and their assigned age estimates are shown in Figure 18.

#### METHODS

#### Abundance

The abundances of individual nannofossil species are defined as follows:

Rare: <0.1% (of the total assemblage)
Few: 0.1-1.0% (of the total assemblage)
Common: 1.0-10.0% (of the total assemblage)
Abundant: >10.0% (of the total assemblage).

#### Preparation

Smear-slide preparation followed standard procedures: a small piece of sediment was smeared onto a glass slide with a drop of water using a flat toothpick. A cover-slip was then mounted. Samples studied using scanning electron microscopy (SEM) were dispersed in water in a glass vial using ultrasonic vibration for about 30 s. A few drops of the suspension were pipetted onto an aluminium SEM stub, dried, and coated.

## PHYSICAL PROPERTIES

We measured compressional-wave velocities and index properties (bulk density, porosity, water content, and grain density) on the crystalline rocks recovered from Sites 733 and 735. Experimental details are described next.

### Compressional-Wave Velocity

The pulse-transmission method was used to determine the compressional-wave velocity using ultrasonic piezoelectric transducers as sources and detectors in a screw-press Hamilton Frame described by Boyce (1976). Early tests indicated that the flatness and parallelism of the specimens determined the accuracy and reproducibility of the measurements. Accordingly, grinding fixtures for finishing the samples were designed and built and their use permitted achievement of flatness and parallelism to within 0.005% to 0.025% of the transmission distance. This small tolerance resulted in sharply defined first arrivals of the direct *P*-wave mode. Three types of specimens were used in this apparatus: (1) minicores (24.6 mm in diameter, 15–20 mm long) drilled normal to the core splitting plane (i.e., horizontal) and parallel to foliation, (2) cubes (21 × 21 × 21 ± 1 mm) cut with faces parallel to foliation (pulse transmission direction A), perpendicular to lineation (direction B) and perpendicular to foliation (direction C), and (3) half-round cores cut from the working half of the core, with lengths varying between 25 and 61 mm but typically 58.4 mm. The pulse transmission direction was along the core axis (direction A) and therefore vertical. Half-round cores were prepared for samples having a grain size greater than 5 mm, and cubes were prepared for rocks that were strongly foliated. Measurement uncertainties in transmission length (± 0.05 mm, ±0.25% of length) and timing uncertainties (±0.035 s or 0.1%) yielded nominal uncertainties in $V_p$ of about 0.3%. Calibration against velocity standards (leucite $V_p$ = 2.745 km/s and silica glass $V_p$ = 5.97 km/s) were reproduced to within 0.3%. Measurement of $V_p$ in an aluminum standard resulted in a velocity of 6.379 ± 0.022 km/s, about 1% higher than the nominal velocity of 6.295 km/s. We believe this calibration value is in error. In practice, heterogeneity of the rock samples and irregularities in the sample shapes and finishes degrade this experimental accuracy to about 0.8% or $5 \times 10^{-2}$ km/s.

### Index Properties

Wet and dry densities, porosities, and water contents were determined on all of the minicore samples using a motion-compensated microbalance measurement of mass (±0.010 g accuracy) and a Penta-pycnometer measurement of sample volumes (±0.03%) in both the saturated and dry states. Samples were dried at 110° ±5°C for 24 hr to drive off water. Purge times of 5 min were used, and overall accurracies of bulk and grain densities are about 0.2% or $6 \times 10^{-3}$ Mg/m³. Porosities were determined to probably no better than ±0.2%, assuming that the porosity is interconnected and fluid saturated.

## THERMAL CONDUCTIVITY

Core samples were measured nondestructively for thermal conductivity in the shipboard laboratory. Measurements were performed over about 5 to 6 min with a heated needle probe sandwiched between the sample and a slab of low-conducting

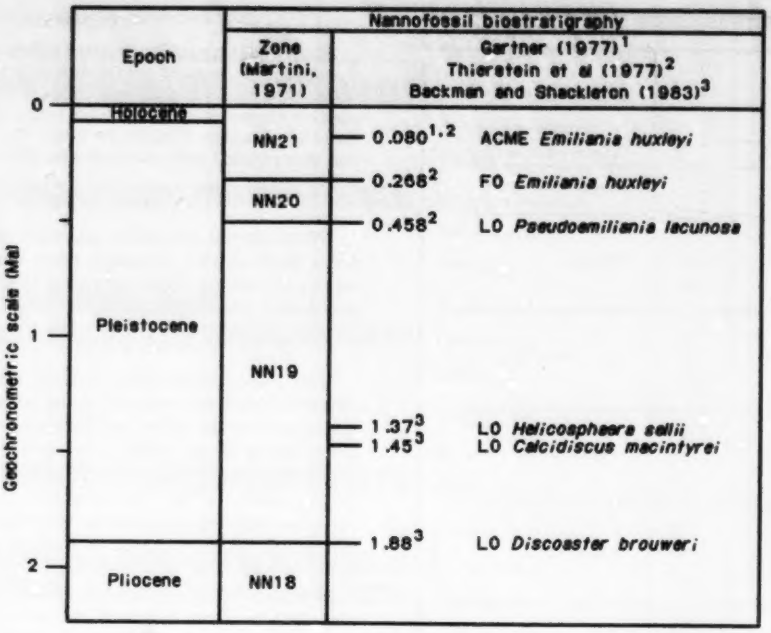

Nannofossil biostratigraphy
Epoch
Zone (Martini, 1971)
Gartner (1977)¹
Thierstein et al (1977)²
Backman and Shackleton (1983)³
Geochronometric scale (Ma)
0
1
2
Holocene
Pleistocene
Pliocene
NN21
NN20
NN19
NN18
0.080¹·² ACME Emiliania huxleyi
0.268² FO Emiliania huxleyi
0.458² LO Pseudoemiliania lacunosa
1.37³ LO Helicosphaera sellii
1.45³ LO Calcidiscus macintyrei
1.88³ LO Discoaster brouweri

Figure 18. Pleistocene nannofossil zonation events used during Leg 118 with estimated absolute ages. FO = first occurrence; LO = last occurrence.

material (Vacquier, 1985). This method is most convenient for the hard-rock cores, which were cut in the form of a half-round cylinder because this shape is easily adapted for the apparatus.

The theory of the method closely approximates the heating of a line source in a plane separating half-spaces of the sample material and a thermal insulator, which in turn is a relatively straightforward extension of the method of heating of a uniform full-space by a line source (Jaeger, 1956; Von Herzen and Maxwell, 1959). If the substrate on which the sample is placed were a perfect thermal insulator, the rise in temperature with time at the needle probe would be exactly twice that experienced by the probe in an infinite medium having the same thermal conductivity of the sample. In practice, the low-conducting substrate absorbs a fraction of the heat during measurement, which depends on the ratio of sample to substrate conductivity. For most of the rock samples measured during Leg 118, this ratio was large enough (>15-20) so that the adjustment from the simple theory requires a relatively small correction. This correction was determined by carefully measuring materials of known conductivity having values close to those measured in the samples.

Measurements of rock thermal conductivity by this technique were conducted sporadically during previous ODP legs. Measurements on nine basalt samples were reported from Leg 109, Site 648 (Shipboard Scientific Party, 1988b, Table 20), as well as from Leg 111, Hole 504B (Shipboard Scientific Party, 1988c, Table 27). These studies indicated that the multiplying factors to convert the conductivity value calculated from the full-space theory to the actual value represented by the samples ranged from about 2.1 to 2.7, apparently depending on the time period used after initiation of the transient experiment. These factors were obtained by comparing values for standard materials determined over the same time periods in the same apparatus. The following discussion presents some reasons why such unexpectedly large and variable correction factors were determined, and some suggestions for improving the measurements.

## Measuring Techniques

### Calibration Standards

To improve the accuracy of the data obtained, two new calibration standards were used during Leg 118. One was a plate of fused silica glass, about 10.3 × 10.3 × 2.5 cm, with uniform and well-established conductivity (1.38 W/m/K; Clark, 1985). This was used in place of the thin (0.6-cm-thick) plate available previously, which gave confusing results during previous legs for any measurements lasting more than 1-2 min (see below). The other new standard is a slab of synthetic material designated "Macor" having a conductivity reported as 1.68 W/m/K by the manufacturer, near the values expected for igneous rocks of the oceanic crust. This material was obtained in the form of a short cylinder about 10.3 cm in diameter by 8 cm long, which was cut in half along the axis to give it the same shape (although somewhat larger) as the half-round core sample sections.

### Calibration Tests

Before and during the measurements on samples, several measurements were performed using both of the above calibration standards. These measurements were run over a transient needle-probe heating duration of 6 min to determine the best period over which data should be obtained. Almost all of the measurements produced the same heating pattern: an initially steep slope of temperature vs. *ln* time over the first 60 to 90 s that gradually decreased to a more uniform slope and sometimes trailed off to a slightly reduced slope over the last minute (Fig. 19). To reduce the effects of any external temperature changes, all calibration runs were performed when the temperature of the standard in the bath was changing at a rate less than 0.01°C/min. The data reduction program will remove a linear temperature change, but inaccuracies occur if the change is too rapid or nonlinear.

Measurements using these calibration standards were analyzed for two different time periods of data acquisition: one during the early (30 to 66 s) period of rapid, quasilinear change

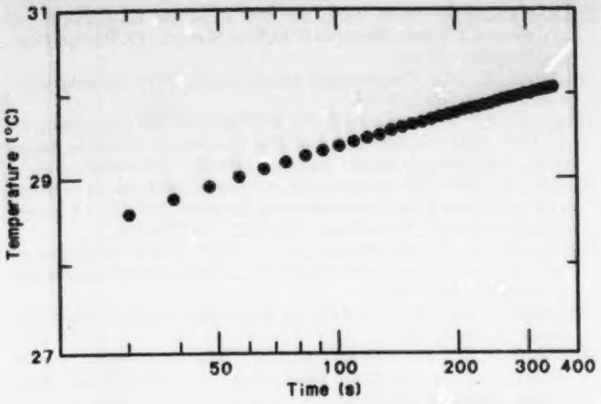


Figure 19. Typical plot of the data from measuring thermal conductivity of a rock sample using the needle probe and half-space method. Note that the slope of the temperature vs. *ln* time relationship is steeper over the first few data points and tends to a linear relationship after 60 to 90 s.

of temperature vs. *ln* time, and the other over the later (60-90 s to 5-6 min) period with a nearly linear relationship (Fig. 20). The results show that the *F* factors (i.e., the factors necessary for multiplying the result to obtain the standard value, assuming that the needle probe was measuring in an infinite medium of the calibration material) are separated into two groups, depending on the time interval of the data. For the early transient period, the *F* factors range widely from about 2.2 to 2.8, which is significantly greater than expected theoretically (Vacquier, 1985), whereas for the later linear period of the data, the *F* factors cluster around a value of 2.0 (Fig. 20).

These results suggest that more accurate and uniform values could be obtained by using the data over the period of measurement from about 1 to 6 min. The more scattered results over the early time period with anomalously high *F* factors may be explained by several effects. Most important is probably that the needle probe is not mounted exactly symmetrically between the low-conductivity substrate of the experimental apparatus and the sample (or standard); rather, it is flush with the surface of the substrate, so that the initial period of heating will be affected more strongly by its low conductivity, which explains the systematically higher slopes and higher *F* factors. The scatter of the early time results may also result from the variability in surface roughness of the sample, or in the amount of grease used to improve thermal contact between the substrate and the sample or calibration standard. A low-conducting silicon grease was used for convenience; a higher-conductivity grease might alleviate this problem to some extent. However, although use of a higher-conducting grease might reduce some of the scatter in the results, it seems unlikely to eliminate the anomalous systematic differences between early and late time measurements described above.

Note that the mean *F* factor for the silica glass standard is 1.94, whereas for the Macor standard it is 2.01, using the standard values given above. The former value is near that expected (1.95) when using the empirical relationship proposed by Vacquier (1985, Eq. 5), whereas a factor of 2.0 could only be approached (not exceeded) for a very large ratio of sample to substrate conductivity. We surmise that the conductivity of the Macor standard is somewhat lower than the value quoted. Assuming that the average *F* factor for Macor should be about 1.96 because it has significantly higher conductivity than silica glass, we estimate the conductivity of this standard as 1.64 W/m/K.

## HARD-ROCK PALEOMAGNETISM

Paleomagnetic measurements were performed on minicore samples taken from selected areas within recovered cores. These areas were chosen on the basis of lithologic homogeneity and the ability to orient the samples with respect to the vertical direction. When possible, at least one shipboard sample was taken from each core. However, a few cores consisted only of unoriented fragments and thus were not sampled.

Magnetic susceptibility ($X_0$) was measured using a Bartington Magnetic Susceptibility Meter (Model MS1). This value of initial susceptibility was used in conjunction with natural remanent magnetism (NRM) values to calculate the *Q* ratio (Koenisberger) of the samples. A field value of 0.38 Oe was assumed for Site 735 so that

$$Q = \frac{\text{NRM}}{(X_0 \times 0.38)}.$$

Remanent magnetization was measured with a MOLSPIN Portable Rock Magnetometer. This spinner-type magnetometer interfaced with a DEC PRO-350 microcomputer using software written by Yozo Hamano for Leg 109. Step-wise alternating field (AF) demagnetization was performed with a single-axis Schonstedt Geophysical Specimen Demagnetizer (Model GSD-1) at 25, 50, 75, 100, 150, 200, 250, 300 Oe, and upward in 100-Oe steps until the specimen decreased to below 15% of the NRM and a stable inclination was identified on a Zijderveld plot. In addition, thermal demagnetization was performed on selected samples using a Schonstedt Thermal Specimen Demagnetizer (Model TSD-1) and steps of 100, 150, 200, 250, 300, 350, 400, 440, 480, 520, 540, 560, 580, and 600°C.

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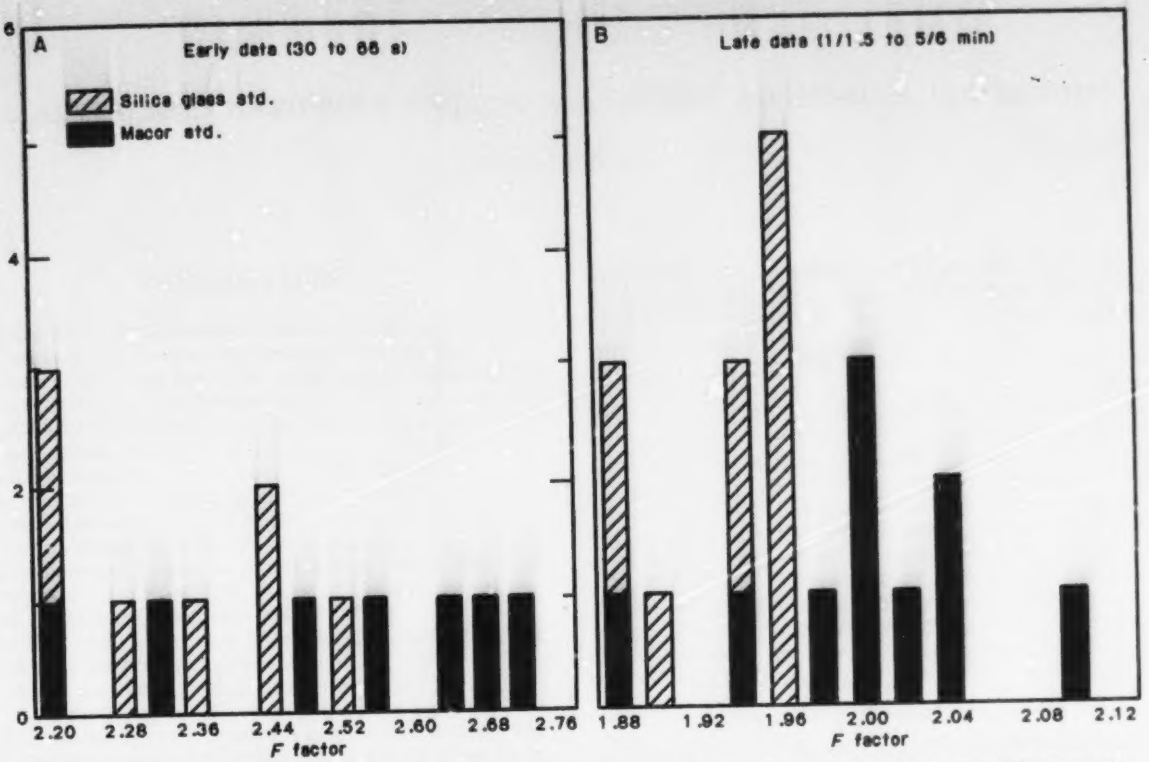

Figure 20. Histograms of the "*F*" factors (see text) calculated for measurements of thermal conductivity standards over different periods of time after initiation of heating of the probe. Note that the horizontal scale divisions for the early data (A) are twice those for the late data (B). Values for standards assumed as 1.38 W/m/K for silica glass, and 1.68 W/m/K for Macor.

# 2. ADVANCES IN HARD-ROCK DRILLING AND CORING TECHNIQUES, ODP LEG 118[1]

Steven P. Howard[2]

## INTRODUCTION

During Leg 118, 12 shallow exploratory holes were cored in the Atlantis II Transform on the Southwest Indian Ridge. These holes were drilled using the 9.5-in. positive displacement coring motors (PDCM) on the sides and bottom of the transform valley in 3000–5000 m of water. All holes were spudded using newly developed drilling hardware and techniques, with little or no bottom-hole assembly (BHA) support and stabilization.

The information obtained by drilling these exploratory holes using the 9.5-in. coring motors helped to select Site 735, where a hard-rock guidebase (HRGB) was set. A guidebase was deployed in 731 m of water. During an 18-day drilling period, 500 m of gabbro was cored in Hole 735B. A total of 434 m of core was recovered for an average recovery rate of 87%.

The time spent conducting unsupported exploratory coring allowed us to field test extensively these 9.5-in. coring motors. Running the guidebase, testing the core bit extensively in Hole 735B, and deploying the navidrill resulted in significant increases in knowledge and experience in hard-rock drilling. The Ocean Drilling Program (ODP) will use the results of this hardware development during Leg 118 as key building blocks for future development of crustal coring systems designed to drill and core fractured hard-rock formations.

## EASTMAN-CHRISTENSEN 9.5-IN. POSITIVE DISPLACEMENT CORING MOTOR

### Overview of Unsupported Spudding Operations in Leg 118 Single-Bit Holes

Twelve shallow holes were spudded at Sites 732, 733, 734, and 735 using Eastman Christensen's 9.5-in. positive displacement coring motor (PDCM). The PDCM provides up to 6000 ft-lb of torque at 90 to 120 rpm. Flow rates of 400 to 600 gal/min are required to rotate the motor downhole. A 30-ft core barrel, run in on wireline, is landed in the hollow rotor section of the motor. This rotor is connected to the drill string through the drive sub assembly. As fluid passes across, rotor and stator torque is generated. This torque rotates the 40-ft-long outer motor housing, which in turn induces torque and rotation to the 10.5-in. outside diameter × 2.25-in. roller-cone core bit. After cutting a 30-ft cone, the core barrel is retrieved by wireline, completing the coring cycle (Fig. 1).

The PDCM allows the entire drill string to remain stationary. Only the core bit and motor housing rotate. In addition, because the drill string remains stationary, one can use the newly developed real-time television/sonar system on the drill string to monitor stability of the bottom-hole assembly (BHA) and bit confinement during critical spudding operations. Combining the use of the PDCM with the television/sonar system makes it possible to conduct exploratory coring operations efficiently and reliably with an unsupported BHA (Fig. 2). We lost no BHAs during operations using the PDCM. Before the advent of PDCMs, many BHAs were lost while attempting to spud bare-rock sites during the Deep Sea Drilling Project.

A total of 142 m of hole was drilled during 95 hours of rotation. All of these holes were spudded using an unsupported BHA. A total of 9.6 m of core was recovered. This low core recovery was attributed to coring with an unsupported BHA and to encountering significant amounts of surface rubble at many of the drill sites (see "Introduction and Explanatory Notes" chapter, this volume). Although core recovery was low, we did obtain considerable information about drilling characteristics and formation types in the 12 exploratory holes. This information was used to eliminate undesirable drill sites. The chances of setting a reentry structure (reentry cone and guidebase) on a site where a 200+-m scientific objective could be reached during the time allocated for a single drilling leg were enhanced significantly using unsupported coring and drilling techniques.

### Unsupported Spudding Procedures

Rotation of PDCMs was established during spudding with flow rates as low as 150 gal/min, with 5000 lb weight on bit, and with a surface pump pressure of 200 psi. Drilling parameters were increased slowly to 600 gal/min, 5,000 to 10,000 lb weight on bit, and 1500 to 1600 psi pump pressure. Flow rates and weight on bit varied owing to seafloor conditions, the amount of sediment or surface rubble present, and the formation being drilled. Drilling parameters increased as a function of increased bit confinement and increased amount of BHA buried below the seafloor.

The coring motor BHA consisted of a 10.5- × 2.25-in. roller cone core bit, a 9.5-in. coring motor, a crossover sub, five 8.25-in. drill collars, another crossover sub, a 7.25-in. drill collar, a crossover sub, and six stands of 5.5-in. drill pipe. We tried to keep the neutral point in the BHA as low as possible. Typically, 10,000 lb of weight was run on the bit during the initial spudding. The television/sonar system was used to provide immediate feedback about bit confinement and BHA stability—parameters used to govern the amount of motor torque, rotational speed (revolutions per minute), and weight on bit that could be run.

Although the bit remained on bottom during all spudding operations, heave-induced fluctuation of weight on bit could be seen from cyclic torquing of the drill pipe (observed with the television/sonar system) and by fluctuations in pump pressure at the surface. Note that these observed cyclic fluctuations in drill-string torque and indicated surface pump pressure were not always synchronized with the period of ship's heave. A combination of frictional dynamics of the bit may also have contributed to the cyclic fluctuations observed.

### Operating Characteristics of the PDCM

Figure 3 shows operating pressure as a function of flow rate. The graph reflects a spread of operating pressures observed while conducting unsupported coring operations in a number of exploratory holes. Drilling parameters were (1) 1000 to 10,000 lb

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Ocean Drilling Program, 1000 Discovery Drive, College Station, TX 77840.

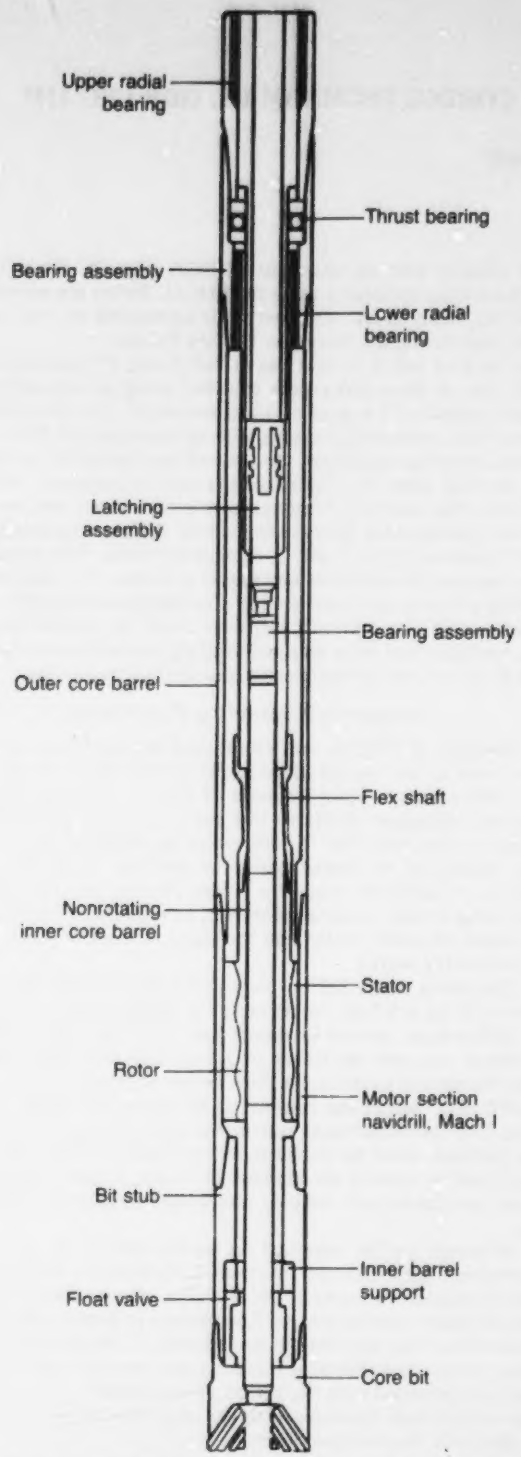
Upper radial bearing
Thrust bearing
Bearing assembly
Lower radial bearing
Latching assembly
Bearing assembly
Outer core barrel
Flex shaft
Nonrotating inner core barrel
Stator
Rotor
Motor section navidrill, Mach I
Bit stub
Inner barrel support
Float valve
Core bit

Figure 1. Diagram of the 9.5-in. positive displacement coring motor.

weight on bit, (2) 2.5-ft average surface heave (as measured by the heave compensator position indicator), (3) 4.5-s average wave period, and (4) an average water depth of 3800 m. Data were taken while working at Sites 732 through 735.

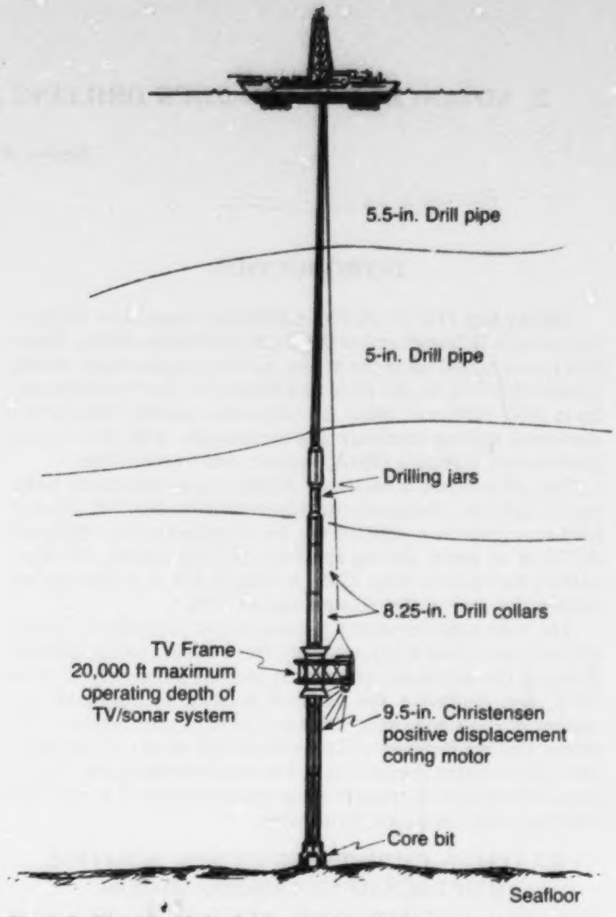
5.5-in. Drill pipe
5-in. Drill pipe
Drilling jars
8.25-in. Drill collars
TV Frame 20,000 ft maximum operating depth of TV/sonar system
9.5-in. Christensen positive displacement coring motor
Core bit
Seafloor

Figure 2. Diagram of the 9.5-in. positive displacement coring motor showing the unsupported bottom-hole assembly.

Figure 4 reflects stall pressures as a function of flow rate. The driller can compare real-time flow rates and operating pressures to both curves to ascertain if the coring motor is rotating properly downhole.

### Mechanical Evaluation of the PDCM

While tripping into Hole 733A with the core barrel latched in the coring motor, a piece of rubber from a drill-pipe stabbing guide came loose and fell down the drill pipe. Because fluid was pumped down the pipe to operate the motor, the rubber became lodged between latch fingers. After repeated attempts to engage the latch fingers with the core-barrel pick-up sleeve, the lip of the pick-up sleeve finally caught on the edge of the overshot pulling neck, allowing the core-barrel assembly to be retrieved from the hole. Apparently, this rubber piece had jammed in the latch, caused the latch fingers to collapse, and allowed the core barrel to unseat during coring operations. Seawater was pumped through the motor at a high flow rate to ensure that all restrictions (e.g., rubber, debris, latch, etc.) were cleared. A second core barrel was run in on the wireline and latched into place as coring continued.

During a coring run at Hole 733D, a core-barrel connection failed. The core-barrel-box connection that makes up the bearing assembly failed because of a lack of torsion. This was caused by rocks in the throat of the bit, which induced columnar buckling of the core barrel, as well as torque to the core barrel from the bit and bit sub. The lower end of the core barrel was seized

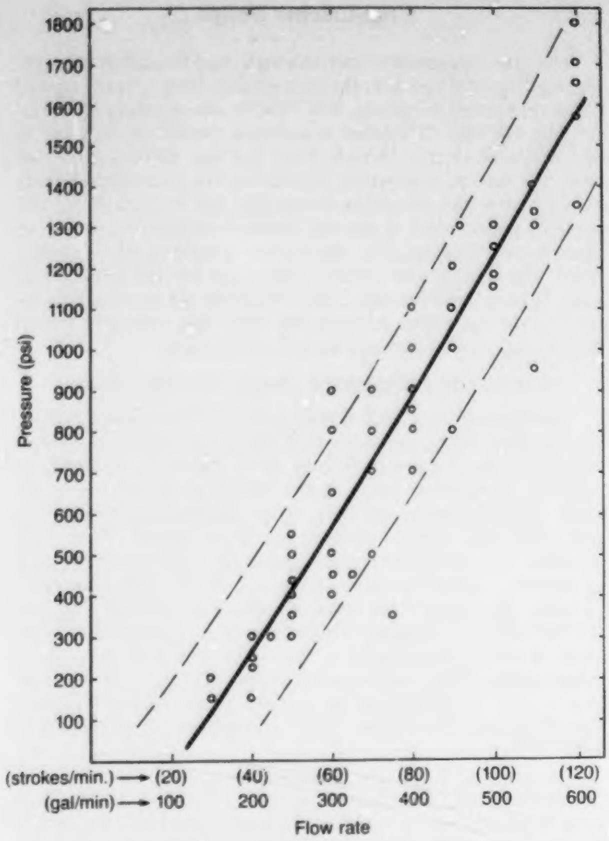

Figure 3. Plot of 9.5-in. Eastman Christensen coring-motor operating pressures as a function of flow rate. Parameters for Sites 732 through 735: weight on bit fluctuation = 1,000–10,000 lb; surface heave = 2.5 ft; heave period = 4.5; average water depth = 3800 m. Dashed lines = operating limits; dots = data points; solid lines = best-fit lines.

and jammed in the throat of the core bit with finely ground cuttings, and required a sledge hammer to remove it. The rotor/stator and bearing assembly were also full of cuttings. These were removed by circulating seawater through the motor at the surface.

While using the coring motor in Hole 734A, we again encountered difficulty when retrieving the core barrel. It took several attempts to retrieve the core barrel successfully. Once the core barrel was at the surface, we found that it was missing two latch fingers. Presumably, the missing latch fingers fell out the end of the bit. A second core barrel was run and latched into place. Before spudding a new hole, we attempted to retrieve the core barrel to check that it was not jammed and that the missing latch fingers were not in it. However, we found that the core barrel had jammed, and after repeated unsuccessful attempts to engage the latch fingers with the pick-up sleeve, we pulled the coring motor out of the hole. We found that the latch was packed, fouled with rust and scale from the drill pipe, and one latch finger was broken. The rust packed between the latch fingers acted as a fulcrum, resulting in the latch-finger pins failing radially outward when the pick-up sleeve engaged the top of the latch assembly. After we removed the core barrel from the coring motor, we found that a latch finger lost during an earlier run was jammed inside the core catcher.

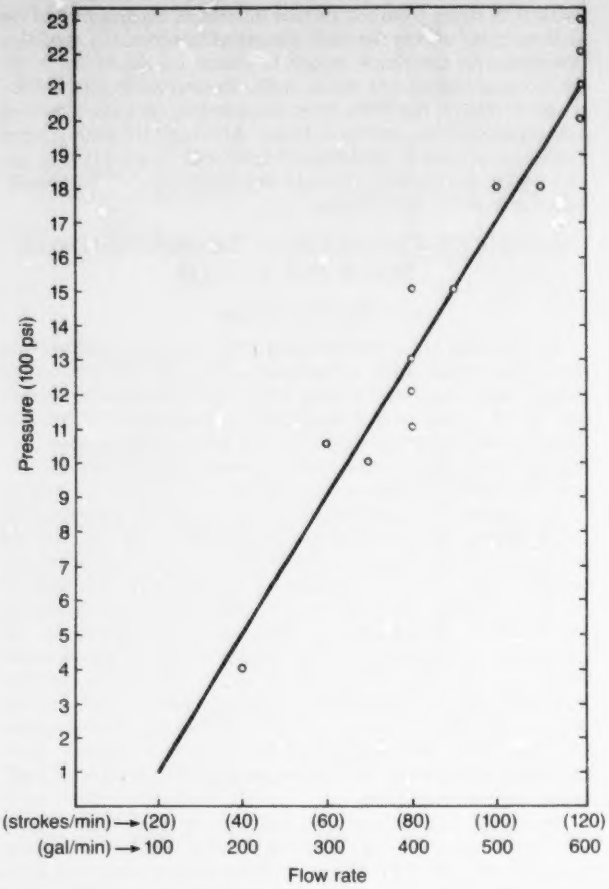

Figure 4. Plot of 9.5-in. Eastman Christensen coring motor stall pressures as a function of flow rate. Parameters for Sites 732 through 735: weight on bit fluctuation = 1,000–10,000 lb; surface heave = 2.5 ft; heave period = 4.5; average water depth = 3800 m. Solid lines = best fit line; dots = data points.

While coring gabbro at Hole 735A, the pin connection on the bit sub failed. This site was free of sediments, and the walking action and skidding of the bit during the initial spudding showed that the seafloor was very hard. After 11.25 hr of rotation and 7 m of penetration, the Hycalog pin connection failed, which resulted in loss of the bit. This failure was attributed to (1) bending stresses induced in the bit sub by the unsupported BHA and (2) high cyclic torsional loads induced by repeated stalling of the coring motor, which was associated with heave-induced fluctuating bit weight. Note that after the pin connection failed, the core-barrel assembly remained intact, even though a significant amount of weight and torque from the coring motor was transmitted into the end of the core barrel that protruded from the end of the bit sub.

PDCMs have proven very effective for spudding into a variety of formations (e.g., gabbro, basalt, hydrothermal black smoker deposits, and peridotite) with an unsupported BHA. Use of the PDCM for unsupported exploratory drilling offers a reliable way to spud holes in all types of oceanic rocks in areas having unusual seafloor relief (e.g., Leg 118, with slopes up to 45°). The limited amount of torque available (600 ft-lb) and the considerable stability of the BHA provided by not rotating the entire drill string from the surface minimizes overloading of the drill assembly during the early phases of unsupported spudding operations. If too much weight is placed on the bit or if the BHA is side loaded, the motor stalls. To reestablish effective rotation of the bit, the BHA must be picked up, thereby removing any undesirable or excessive force. Although progress is slow during unsupported spudding of hard rock (e.g., gabbro), use of a coring motor allows shallow exploratory holes to be established effectively and reliably.

## EFFECT OF ENGINEERING DESIGN CHANGES MADE FOR LEG 118

### Bearing Design

Prior to Leg 118, a new bearing design was incorporated into the coring motor drive subassembly. The Leg 106/109 coring motors used a bearing/housing connection that required a special set of screws and thread-locking compound to lock the thread connections together. The new bearing design used during Leg 118 incorporated a more conventional shoulder connection that allowed higher torques to be used to lock it in place.

The bearing-drive subassembly held up well during the difficult spudding operations encountered during Leg 118. PDCM M148 was rotated downhole for 95 hr and motor M147 was rotated for 49 hr (Fig. 1). Longitudinal bearing play was 0.120 in. for motor M148 and 0.107 in. for motor M147. Both motors had 0.0709 in. of bearing play before being run downhole. All coring was performed with the PDCM using an unsupported BHA. Use of unsupported BHAs increases significantly the load on the bearings, compared with loads in conventional drilling. We consider the low amount of observed bearing wear as good. Not only is the new longitudinal bearing design superior from the standpoint of wear, but this design adds considerable strength to the drive subassembly.

We found that the new 15-5 PH stainless steel latch fingers were much stronger than the cast steel latch fingers used during Legs 106 and 109. All problems with the latch system were associated with debris (e.g., rust, scale, rubber, etc.) and fouling or jamming of latch fingers. Although several latch fingers were lost downhole, the fingers themselves did not fail structurally; the threaded hinge pins holding the latch fingers in the latch body sheared off. The accumulation of rust and scale between the latch fingers resulted in the hinge latch pins overloading and shearing radially outward when the pick-up sleeve engaged the top of the latch fingers. These hinge pins acted as a safety device when the latch fingers became overloaded and prevented severe damage to the internal coupling-bonnet latch groove and landing shoulder.

### High-Strength Core Barrels

New high-strength core barrels, with new tapered thread connections, held up well during difficult drilling conditions. During both Legs 106 and 109, core barrels repeatedly failed. These failures occurred at the surface during handling of the core-barrel assembly on the rig floor, as well as downhole during coring. Failures that occurred at the surface were tensile-bending (impact load) failures, and the downhole failures were torsion-induced failures. The only core-barrel failure during Leg 118 was associated with a core jam, as described earlier. The new core barrels were rugged and withstood repeated redressing on the rig floor, as well as routine handling overhead. The only special precaution we took was to lock the threads with a thread-locking compound to prevent the core barrels from backing off downhole. This also prevented vibration from the motor or torque induced by intermittent contact with the bronze bit-sub support bushings and bit throat. Locking the threads caused no thread-galling problems, unusual wear, or loss of time.

### Core-Catcher Design

The new core-catcher used during Leg 118 performed well. During Legs 106 and 109, the core-catcher body threads backed off on numerous occasions. The PDCM core catchers used during Leg 118 were redesigned to enhance overall strength and to stop the core-catcher threads from backing off downhole. At first, the service connection threads on the core-catcher body were locked with a threading compound, but the fine threads repeatedly galled when re-dressing the core-catcher fingers, so we discontinued this practice. No further problems were encountered. The core-catcher service connection was left-handed and never backed off downhole. The tapered thread core-barrel connection on the upper core-catcher body was routinely locked during each coring run and caused no problems.

### Further Recommended Design Modifications

Development of a latch system that is not susceptible to fouling by debris falling inside the drill string is desirable. If it is impractical to build a new latch because of clearance problems, relocation of the flow ports in the coupling bonnet below the latch assembly would alleviate, or at least minimize, the rust and scale that collects between the latch fingers. Now, flow ports for the motor are located above the latch-head assembly to prevent or minimize washing out any of the latch-head components. Because of the relatively short periods of time the latch assembly is exposed to high flow rates downhole, replacement of latch components as they wear over long periods of time should not be a major operating cost. Consideration should also be given to enhancing the strength of the core-barrel latch system so that this system can be allowed to fall freely downhole.

The original (Legs 106/109) core-barrel latch assembly was not mechanically strong enough to fall freely down the drill pipe. By increasing the interval clearance in the PDCM (Leg 118 design) rotor, core barrels having larger diameter (heavier) could be used. If the core barrel could fall freely down the drill pipe one time, a wireline trip could be eliminated for each core run. Now, we must deliver the core-barrel assembly by wireline, rather than free falling, as is conventionally done with other standard ODP core-barrel assemblies.

The strength of the core-barrel system cannot be enhanced by increasing the size or diameter of the core barrel further because of limited internal clearance of the coring motor. However, it may be metallurgically possible to increase the strength and toughness of the material from which the core barrel and latch assembly are made at a nominal cost.

The failure of the pin connection on the bit sub of motor M148 was attributed to the unusually high bending and torsional stresses associated with unsupported coring operations. To increase the strength of the bit sub, the inside bore diameter of the Hycalog pin connection could possibly be reduced by 0.250 in. This, coupled with increasing the strength and toughness of the bit-sub material, should enhance the strength of the bit sub considerably. However, one then would have to modify the diameter of the float valve to fit into the reduced bore of the bit sub (Fig. 1).

## HARD-ROCK GUIDEBASE

### Assembly and Deployment

Details of the hard-rock guidebase (HRGB) assembly and deployment (Fig. 5) have been described by the Leg 106/109 Shipboard Scientific Party (1988). Additional details are given in the ODP in-house engineering assembly and operations manual. During Leg 118, the HRGB was assembled, deployed through the moon pool, manipulated from vertical to horizon-

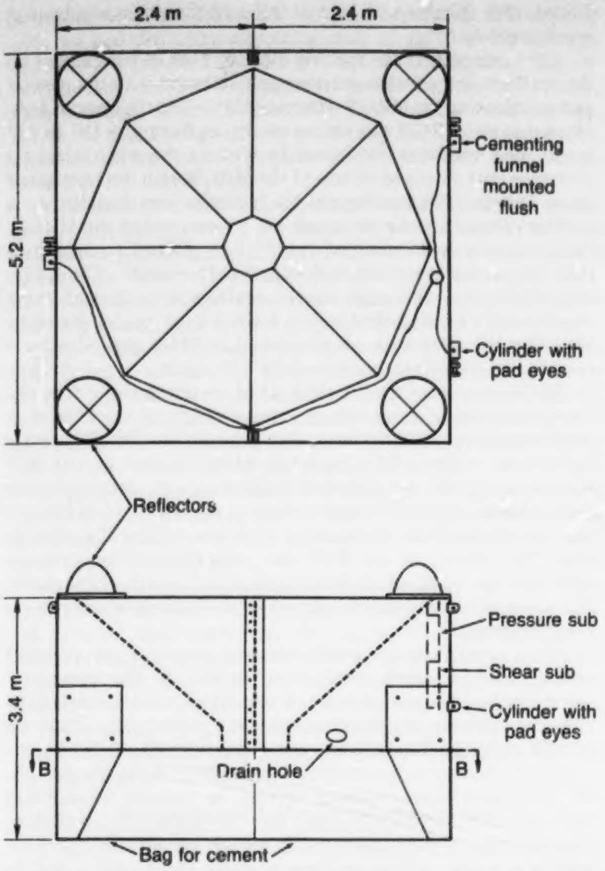
2.4 m
2.4 m
5.2 m
Cementing funnel mounted flush
Cylinder with pad eyes
Reflectors
Pressure sub
Shear sub
Cylinder with pad eyes
3.4 m
B
Drain hole
B
Bag for cement

Figure 5. Top and side views of the HRGB. The 18,000-kg guidebase stands on four legs, is 5.2 m square, and 2.3 m high. The cone inside the guidebase is 26 ft (4.9 m) in diameter and 6 ft (2.8 m) deep (after Shipboard Scientific Parties, 1988).

tal below the keel, and reassembled, and the rig floor was prepared for tripping the guidebase to the seafloor in a total of 18.75 hr (Figs. 6 and 7). Of this, 5 hr was required to disassemble and reassemble the rotary table plug. The time taken to lower the HRGB 734 m to the seafloor, to space out the drill pipe in preparation for its landing on the seafloor at Site 735 (Hole 735B), to pick up the cementing head, and to land it on the seafloor required 4.5 hr. Actuating the pressure sub, pumping 1864 ft$^3$ of 15.5 lb/gal cement, and releasing the kelly hose from the HRGB took 4.75 hr. Total time required to assemble, run, release, and cement the HRGB on the seafloor was 28 hr. The total time of deployment from the time the first half of the HRGB was picked up and handled through the rig floor, until the first reentry in the HRGB with the unsupported coring motor assembly, was 43.5 hr.

No problems were encountered while maneuvering the HRGB from its storage area adjacent to the laboratory stack to the rig floor by crane, when lowering the the HRGB through the moon pool, or when assembling it in the moon pool. During Leg 106, we did encounter difficulty while transferring the HRGB four-part sling from the crane hook to the rig bails. To alleviate this problem a 50-ft HRGB running cable was attached to the four-part-sling master link. When the HRGB was moved into position over the rig floor, the other end of the 50-ft sling was safely attached to the rig bails. The slack in this sling was then taken

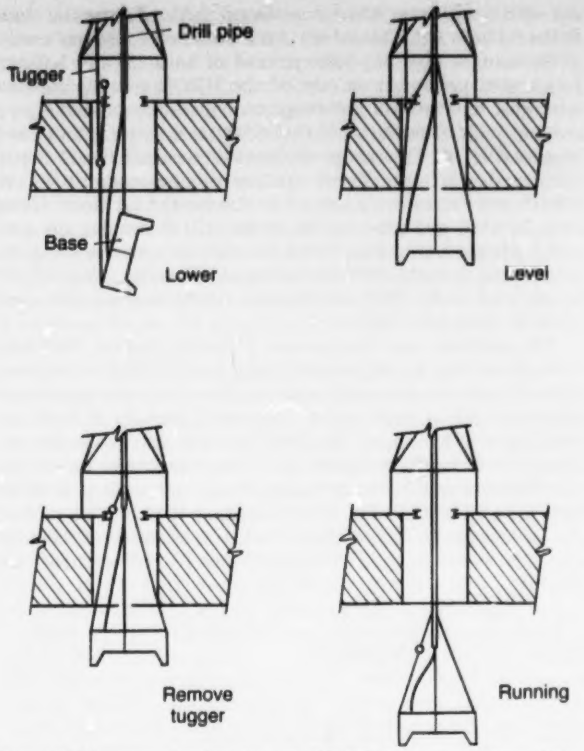
Drill pipe
Tugger
Base
Lower
Level
Remove tugger
Running

Figure 6. Diagrams showing steps for HRGB deployment (from Shipboard Scientific Parties, 1988).

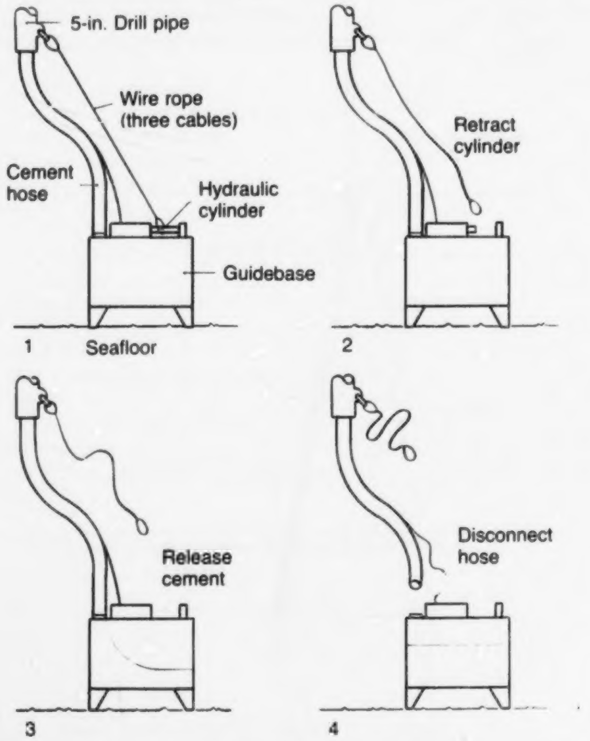
5-in. Drill pipe
Wire rope (three cables)
Cement hose
Hydraulic cylinder
Guidebase
1
Seafloor
2
Retract cylinder
3
Release cement
4
Disconnect hose

Figure 7. Diagrams showing HRGB landing and cementing sequence (from Shipboard Scientific Parties, 1988).

out with drawworks, which transferred the load from the crane to the rig bails and allowed the crane hook to be removed easily.

By using a 15-ft pup joint instead of both 15- and 5-ft pup joints used previously on top of the HRGB running sub, we were able to eliminate the dangerous operation of making up the pup joint connections in the moon pool with rig tongs and tuggers (Fig. 8). The new procedure requires that the 15-ft pup joint on top of the HRGB running sub be made up to the HRGB pad-eye running sub while still on the rig floor. Using only the 15-ft pup joint on top of the HRGB running sub provided adequate clearance below the rig floor for installing the rotary plug with the HRGB running subassembly hung off the moon-pool doors. This modification of the running procedure saved an hour of rig time.

No problems were encountered while tripping the HRGB to the seafloor, but during repositioning, the HRGB 62-ft running cables became fouled on the corners. The tilt beacon confirmed that these cables were fouled, indicating that the HRGB was hanging at a 20° angle. The HRGB again was set on the seafloor, which freed the cables, and then was picked up for the last time to adjust the drill-pipe space out and to allow us to attach the cementing head. The tilt beacon then confirmed that the cables were no longer fouled. Later examination of the cable thimbles at the surface confirmed that the cables had been fouled. One thimble was bent at 90° and the other was bent at approximately 15°.

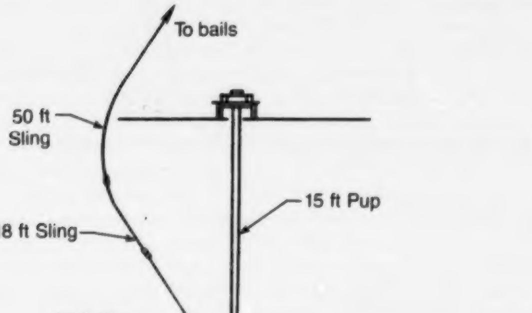

Figure 8. Diagram of the HRGB running configuration with 15-ft pup joint.

After completing the spacing out, the HRGB was landed on the seafloor and a Baker pressure sub actuated with the cement pump, releasing the HRGB running cables. The tilt beacon indicated that the HRGB was sitting on the seafloor at a 10° to 12° angle. This was later confirmed by viewing the mechanical tilt indicator unit mounted on top of the HRGB with the television/sonar system. The mechanical tilt indicator was installed as a backup system for the electronic tilt beacon inside the HRGB. Note that the inclination of the 10.5-in.-diameter cored hole near the surface was measured as approximately 6°. The guide-base sitting at a 12° angle on the seafloor may possibly have contributed to the drilled hole's having a 6° angle. Possibly, spudding the hole with an unsupported BHA may also have contributed significantly to the hole's 6° angle.

When pressuring up the drill string to pump the 2.5-in.-diameter ball out of the pressure subassembly into the HRGB, a significant pressure shock wave was generated as the ball-release mechanism shifted. This occurred when pressure in the drill pipe reached 3500 psi. The ball shifted rapidly, decreasing the pressure and creating a shock wave that caused the drill pipe to jump at the surface. We heard a loud noise from the concussion. The impact of the drill pipe jumping and the pressure wave may have caused the kelly hose to whip and, either partially or completely, shear the screws in the backup shear sub release mechanism.

After completing the cable releasing sequence, we pumped 1864 $ft^3$ of 15.5 lb/gal cement into the HRGB. The television/sonar system indicated that no cement flowed from the HRGB onto the seafloor, which proved that the cement had filled the HRGB. After we finished cementing, we dropped a 2.687-in.-diameter ball to actuate the Brown collet kelly-hose release sub. We tried many times, without success, to pressure actuate and shift the collet release using the cement pumps, but sufficient pressure could not be built up. To release the HRGB, the kelly hose was slowly picked up, but it came loose with 1,000 to 10,000 lb of overpull. We could not ascertain the exact amount of kelly-hose overpull because of the heave-induced fluctuations of the driller's weight indicator. Also, the ship's heaving made it difficult to get a positive indication as to when the screws in the shear sub failed. After tripping the HRGB running assembly to the surface, we found that the ball was seated properly in the collet release sub. We suspect that the three release-cylinder hydraulic hose connections had been severed from the pressure shear sub assembly when the Baker pressure sub was activated. The resulting three 0.5-in. openings may have prevented the cement pumps from building up pressure on the collet release sub assembly. Use of the mud pumps might have allowed significantly higher flow rates to be generated to overcome the pressure loss associated with the severed hoses and might also have allowed us to activate the collet sub assembly, assuming that the backup shear mechanism was still intact.

While using the television/sonar system to survey the HRGB and the surrounding seafloor, we observed that two of the cement bags were protruding from under the HRGB on the downslope side. This was a good indication that the HRGB had filled with cement. We obtained further confirmation of this when cement was tagged inside the 31-in.-diameter throat of the HRGB with the drilling assembly. In the event that the backup shear sub did release prematurely, we suspect that the pressure-shear sub assembly must have remained inside the HRGB cementing sleeve as a result of friction caused by side loading of the kelly hose, which was coiled on top of the HRGB during cementing.

## Evaluation of Mechanical Design

The new integrally mounted legs saved 2 to 3 hr rig time during assembly and made the assembly much safer than during

Leg 106, when the legs were mounted separately. During Leg 106, we had difficulty mounting each of the four HRGB legs separately. Also on Leg 106, we had difficulty attaching the kelly hose to the HRGB because of interference from the externally mounted cement funnel. The flush-mounted cement funnel on the modified guidebase run during Leg 118 provided adequate clearance for easy attachment of the kelly hose to the HRGB in the moon pool.

Why the Brown collet release-shear sub malfunctioned downhole is unclear. However, the backup systems functioned well and allowed us to accomplish required tasks downhole and to successfully deploy the HRGB. Further investigation and technical evaluation will be necessary to determine the optimal pressure-release sub system for deploying the HRGB in the future.

The tilt beacon provided vital information for deploying the HRGB safely at Site 735, where the seafloor is level and boulders are absent. This was clearly evident when the tilt beacon showed that the HRGB cables had become fouled during deployment. The tilt beacon can also indicate any movement of the HRGB that might occur during subsequent reentry and drilling operations. Information relating to changes in inclination of the HRGB during early stages of drilling is vital because it can significantly affect the operation of the secondary reentry cone and the casing run.

Before logging, drill cuttings that were lying on top of the guidebase were washed off by circulating high flow rates with the core bit positioned near the top of the guidebase. Later, when making a subsequent reentry, an obstruction was encountered that we thought was cuttings that may have bridged the hole off. Another possibile source of material causing the bridge in the hole may have been cement filled bags under the guidebase. These bags had been used to provide additional stability for the structure.

### Recommended Design Modifications

Future HRGB designs should call for one-piece construction and a much smaller size than at present. A reduction in size would allow the structure to be run through the moon pool horizontally, alleviating the necessity of maneuvering the HRGB from vertical to horizontal once it is below the keel. The procedure then would be similar to deploying a standard reentry cone. To avoid fouling the HRGB cables while positioning the structure on the seafloor, the running cable release cylinders should be mounted flush with the top surface on the perimeter of the HRGB reentry cone. To compensate for the smaller HRGB structure, externally mounted bags could be attached and filled with cement on the seafloor to provide additional lateral support, depending on the bit confinement requirements.

Overall, the assembly, running, and release procedures for the HRGB are operationally sound. The HRGB was deployed and a hole established in a very short time. Modifications made to the HRGB and its running hardware, together with improvements made to the assembly-handling sequence after Leg 106, have made running the HRGB much safer and also have saved rig time. We gained valuable experience during Leg 118, and several problems were identified that were not observed when the HRGB was first deployed during Leg 106. These engineering observations will benefit the design and deployment of the next generation of guidebases.

## DRILLING OPERATIONS IN HOLE 735B

### Unsupported Spudding Operations With Eastman Christensen 9.5-in. PDCMs

The use of PDCMs for unsupported bare-rock exploratory drilling offers a reliable way to spud holes in various rock types. PDCMs also allow exploratory drilling in steep, rugged terrain, such as the sides of underwater mountains. Although we obtained considerable information during Leg 118 about the drillability of sites using an unsupported coring-motor assembly, core recovery was low. Core recovery can be affected by operational procedures used when spudding a hole with an unsupported drilling assembly; "bit walking" and BHA movement above the seafloor result in break up of core and jamming of the bit throat. In addition, high flow rates (200-600 gal/min) are required to drive the 9.5-in. positive displacement motors. In softer or unconsolidated formations, the high flow rates required to drive the coring motor may tend to wash the core away at the bit face. Reducing the flow rate to the coring motor or using a bit sub that diverts a large part of the flow back up the hole above the core bit may improve core recovery in soft formations.

Theoretically, with an unsupported BHA, as the depth of the hole increases, core recovery should increase because more of the BHA is stabilized. In turn, this results in the bits running more smoothly at the seafloor. This can be seen clearly when one examines the bit runs made in Hole 735B, with additional BHA support and bit confinement provided by the HRGB.

The unsupported coring assembly in the HRGB used to spud Hole 735B consisted of a 10.5-in. Rock Bit Industries core bit, an Eastman Christensen 9.5-in. PDCM, a crossover sub, five 8.25-in. drill collars, another crossover sub, a 7.25-in. drill collar, a crossover sub, and six stands of 5.5-in. drill pipe.

When the HRGB first entered, firm, drillable cement was tagged in its throat. After contacting gabbro, the PDCM ran smoothly and maintained continuous rotation with little or no stalling. However, variations in the weight on bit, which were induced by heave, resulted in repeated torquing and detorquing of the drill string.

Three roller-cone bits (10.5 × 2.25 in.) were run, one of which used thermally stabilized diamond cutters in the throat of the bit to trim the core. The drilling parameters and conditions existing when these bits were run are listed below:

| | |
|---|---|
| Flow rate: | 400 psi |
| Indicated surface pressure: | 400 psi |
| Weight on bit: | 8,000-10,000 lb |
| Ship heave: | 2-3 ft |
| Heave period: | 4-6 s |
| String weight with blocks: | 260,000 lb |

Using PDCMs, a total of 39 m of hole was drilled in 44.5 hr of rotation. The average penetration rate was 1.4 m/hr. Individual results of the three bit runs are provided in Table 1.

Core recovery was significantly higher with PDCMs in Hole 735B than on those unsupported coring runs made before running the HRGB. The percentage of recovery for bit run 2 is also notably higher than for bit run 1. The low core recovery for bit run 3 was attributed to the diamond cutters in the throat of the bit dragging on the core, rather than cutting it. At the end of the bit run, the diamond cutters were structurally sound but had

Table 1. Results of three bit runs at Hole 735B.

| | Run 1 (Type C-4) chisel (4-cone) | Run 2 (Type C-7) conical (4-cone) | Run 3 (Type C-4) hybrid (3-cone) |
|---|---|---|---|
| Hours of rotation: | 12 | 11 | 17.5 |
| Meters cored: | 6.5 | 14.5 | 18 |
| Penetration rate (m/hr): | 0.54 | 1 | 1 |
| Meters recovered: | 2.3 | 6.25 | 5.6 |
| Recovery rate (%): | 35 | 43 | 31 |

been significantly worn and chipped and were capable of inducing significant drag on the core.

A fourth bit, a hybrid impregnated diamond bit manufactured by Christensen Mining Company, was run with the PDCMs, but no measurable hole was drilled. This bit uses as its primary cutting structure a variable impregnated diamond matrix across the bit crown and a secondary system of thermally stabilized diamond cutters. Drilling parameters for the bit run were as follows: 500 to 600 gal/min, indicated pump pressure of 700 to 1000 psi, and weight on bit of 6,000 to 12,000 lb. After 2 hr of rotation, the bit was tripped to the surface. A total of 10 cm of gabbro core was recovered, with this core having an excellent surface finish. Inspection of the bit face revealed that the outside corner of the crown and the throat of the core bit were rounded to a 0.25 in. radius. The rounding of the outer- and inner-bit crown surfaces resulted in total destruction of the diamond cutting surfaces in these areas. These areas of the bit became bearing surfaces, rather than cutting surfaces, and prevented the bit from advancing farther into the hole. The face of the bit was in good shape and was not polished. Thermally stabilized diamond cutters showed a 30% wear. The outer diameter of the bit showed measurable wear. The surface-set natural diamonds on the outer surface of the crown body were still intact. After inspecting the bit crown, we decided that a higher concentration of diamonds on the outer diameter and on the core gauge would be required. Had the bit advanced any significant distance, we believe that core recovery would have been good.

The performance of the PDCMs in Hole 735B was significantly better than for any coring runs made before setting the HRGB. Using PDCMs inside the HRGB with an unsupported BHA to spud a hole was effective and reliable. The hole was established without loss or damage to any BHA components. Although penetration rates were observed to be lower than during subsequent core bit runs made with the 9.875-in. rotary coring system (RCB), acceptable progress was made and the hole was deepened until it was operationally feasible to switch over to the RCB system.

Although the lower penetration rates associated with PDCMs, as compared to 9.875-in. rotary core bits, are directly related to the limited bit weight that can be run, several other factors should be considered. These include (1) the 10.5-in.-diameter bit must cut 12% more hole area than the 9.875-in. bit, (2) the formation in the upper 50 m of Hole 735B differed in its physical characteristics from that cored with the 9.875-in. core bit deeper in the hole (see Site 735 chapter, this volume), and (3) only minimal weight (5,000–10,000 lb) could be run on the bit because of lack of lateral support for the BHA.

## Rotary Coring Operations and Hole Statistics

Hole 735B was drilled to a depth of 500 m in 18 days. This included the time required for pipe trips, reentries, and BHA inspection. Figure 9 shows time vs. depth for Hole 735B during the 18-day drilling period. A total of 434 m of core was recovered for an average recovery rate of 86.9% (calculated for all Hole 735B bit runs).

After drilling 39 m with the PDCM system, the 9.875-in. RCB system was deployed, and the hole extended by another 461 m in 214 hr of rotation to a total depth of 500 mbsf. A total of 420 m of core was recovered for an average recovery rate of 91% for the nine RCB runs.

The high recovery rate for the RCB is attributed to the massive crystalline nature of gabbro, which lends itself to being cored effectively with a roller-cone-type core bit. Mylonitized zones in the gabbro (i.e., areas having undergone high-temperature deformation, creating fine anisotropic grain structures), however, make the rock very tough. Gabbro has a considerably higher compressive strength than that of granite or basalt. Estimated compressive strengths for the gabbro drilled in Hole 735B range from 40,000 to 50,000 psi for fresh rock (coarse isotropic grain structure), and 100,000 psi for material that has undergone significant mylonitization.

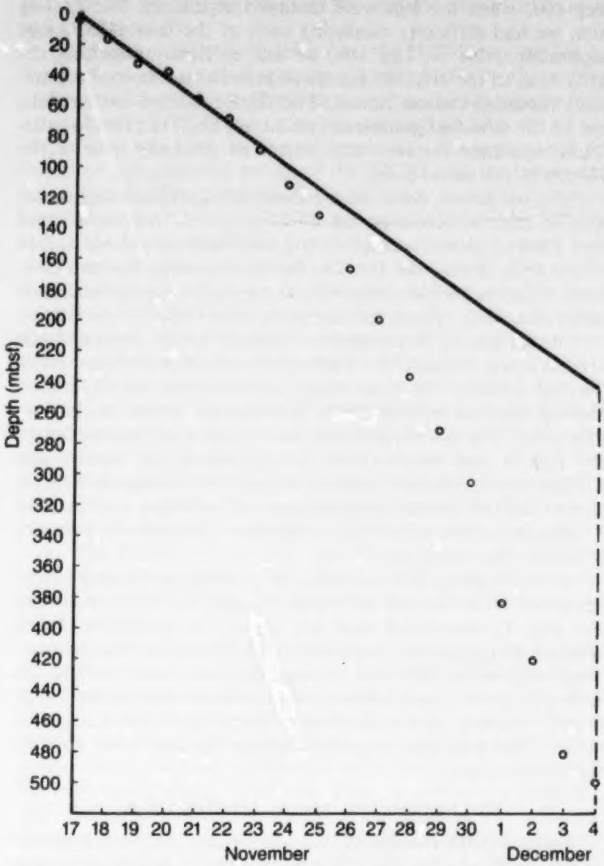

Figure 9. Plot of coring time vs. depth for Hole 735B. Solid line = projected depth at the end of 18 days of drilling; dots = realized depths.

Drilling parameters for the 9.875-in. roller-cone bits were as follows:

| | |
|---|---|
| Rotating speed: | 60 rpm |
| Average hours of rotation: | 24.75 |
| Weight on bit: | 15,000 lb |
| Flow rate: | 325 gal/min |
| Average penetration per bit: | 50 m |

Table 2 summarizes all core bit runs made in Hole 735B (9.5-in. PDCMs and the 9.875-in. RCB systems driven with the top drive). Table 2 shows that core recovery was much higher for the 9.875-in. RCB system than for the 9.5-in. PDCM system. The lower recovery rate associated with the PDCM system was attributed to the following:

1. Most PDCM bit runs were conducted using an unsupported BHA. The BHA's lack of stability above the seafloor produces undesirable bit motion in the bottom of the hole, which breaks up the core as it enters the throat of the bit and causes core jamming. This effect is reduced as the hole is advanced and the BHA is increasingly supported by the surrounding hole.

**Table 2. Core bit statistics for bit runs made in Hole 735B.**

| Bit no. | Bit type | Serial number | Rotating hours | Penetration (m) | Total depth (mbsf) | Length recovered (m) | Recovery (%) | Penetration rate (m/hr) |
|---|---|---|---|---|---|---|---|---|
| Bit runs made with 9.5-in. positive displacement coring motors | | | | | | | | |
| 1-A | RBI 10.5- × 2.25-in. four-cone C4 | AW693 | 12 | 6.5 | 6.5 | 2.3 | 35.4 | 0.54 |
| 2-B | RBI 10.5- × 2.25-in. four-cone C7 | AT516 | 15 | 14.5 | 21.0 | 6.25 | 43.1 | 0.97 |
| 3-C | RBI 10.5- × 2.20-in. three-cone C4 hybrid | AW797 | 17.5 | 18.2 | 39.0 | 5.56 | 30.6 | 1.04 |
| 4-D | Christensen 10.5- × 2.25-in. impregnated diamond hybrid | 7S6749 | 2 | 0.2 | 39.2 | 0.08 | 40 | 0.1 |
| Bit runs made with conventional 9-7/8-in. rotary core-barrel system driven by top drive | | | | | | | | |
| 5-E | RBI 9.875- × 2.312-in. four-cone C7 | AW692 | 19 | 16.8 | 56.0 | 13.31 | 79.2 | 0.88 |
| 6-F | RBI 9.875- × 2.312-in. four-cone C7 | AW690 | 12.25 | 12.3 | 68.3 | 8.43 | 68.5 | 1.0 |
| 7-G | RBI 9.875- × 2.312-in. four-cone C7 | AV721 | 19 | 25.5 | 94.3 | 14.84 | 58.2 | 1.34 |
| 8-H | RBI 9.875- × 2.312-in. four-cone C7 | AW089 | 24.75 | 37.75 | 132.1 | 33.4 | 88.5 | 1.53 |
| 9-I | RBI 9.875- × 2.312-in. four-cone C7 | AV722 | 24 | 39.5 | 171.1 | 36.7 | 93.0 | 1.65 |
| 10-J | RBI 9.875- × 2.312-in. four-cone C7 | AV720 | 26.75 | 67 | 238.1 | 64.48 | 96.2 | 2.51 |
| 11-K | RBI 9.875- × 2.312-in. four-cone C7 | AW088 | 29.5 | 67.5 | 305.1 | 64.87 | 96.1 | 2.29 |
| 12-L | RBI 9.875- × 2.312-in. four-cone C57 | AW764 | 29.5 | 109 | 413.1 | 102.36 | 94.0 | 3.69 |
| 13-M | RBI 9.875- × 2.312-in. four-cone C57 | AW694 | 29 | 86.2 | 508.1 | 81.53 | 94.6 | 2.95 |

2. The intermittent torque and rotation of the PDCM and the PDCM bit tends to break up the core as it enters the throat of the bit. This contrasts with the RCB system driven with top drive, which produces constant torque and bit rotation.

3. The limited weight on bit and reduced flow rates available when using PDCMs with an unsupported BHA result in lower penetration rates, which also may contribute to core jamming problems (i.e., the core has more chances to jam in the core guide because it remains in the bit throat longer before entering the core guide.)

As the hole advanced, penetration rate increased (see Fig. 10), primarily as a function of decreasing degree of mylonitization of the gabbro being drilled. However, a secondary factor contributing to increased penetration rate was an increase in weight on bit from 15,000 to 23,000 lb. In deeper sections of the hole, where penetration rates were 3.7 m/hr (Fig. 10), the high core recovery and good penetration rates were attributed to (1) the massive nature of the gabbro being cored, (2) excellent hole stability (lack of hole break outs and rubble infill), and (3) the effective removal of drill cuttings.

## Evaluation of Core Bit Performance

The 9.875-in. core bits run in Hole 735B were either Type 7 or Type 57 conical inserts. The Type 7 insert is a medium-length conical insert and the Type 57 is a medium-length, multiangled (double) conical insert. Although higher penetration rates were observed with the Type 57 cutting structure, no major difference was noted between the performances of the two cutting structures downhole. The high penetration rates observed with the Type 57 cutting stucture were attributed to an increase in bit weight and the massive nature of the gabbro encountered in the deep sections of the hole where the Type 57 core bits were run (see Fig. 10 and Table 2). The main wear was on the nose inserts, and no discernible wear was noted on the middle or heel rows of cone inserts.

Bearing wear was monitored closely during all core bit runs conducted in Hole 735B. During Legs 106, 109, and 111, cones were lost off bits in as little as 6 hr of rotation, when driven with a downhole motor running at 120 rpm and with 5000 lb of weight. Cones also have been lost off bits that were rotated conventionally, with the top drive at 60 rpm and with 35,000 lb of weight on bit. The bearings of all bits pulled out of Hole 735B were typically graded as 20% to 50% worn. The current ODP four-cone bit design is reliable up to a maximum of 30,000 to 35,000 lb of weight on bit, depending on hole conditions and how much the ship heaves.

We saw that the lower portion of the stabilizer pads on the bits, facing the bottom of the hole, was repeatedly worn 0.0625 to 0.125 in. under the original wear-pad diameter. Typically, the wear band was 1 in. wide. We found that many of the bits with this wear characteristic were in gauge, or only slightly below gauge. These wear pads are typically 0.03125 to 0.0625 in. below hole gauge when bits are new. Because the hole was unusually clean and the wear point localized, we did not attribute wear on the stabilizer pads to rubble, but rather to the cone legs flexing elastically, which caused the cones to pinch in, thus cutting a smaller hole. Deformation of the legs could cause the cones to skid or skew in the bottom of the hole. The change in the loading angle of the bearing may cause accelerated bearing wear. To substantiate this theory further, the last bit run in Hole 735B had a weld failure on one of the cone legs, apparently the result of cyclic flexure stress, possibly induced by the cone leg deforming elastically. The weld crack widened 60% to 70% around the entire perimeter of the weld area of the cone segment. The extent of this weld failure allowed us to knock the cone segment out of the bit body with a sledge hammer.

With respect to the design of future bits, the option to run more weight on bit is operationally desirable. The weight on bit that works well for a particular hole and a specific set of operating circumstances may not work well at a different drill site. Further testing and observation will be necessary to confirm

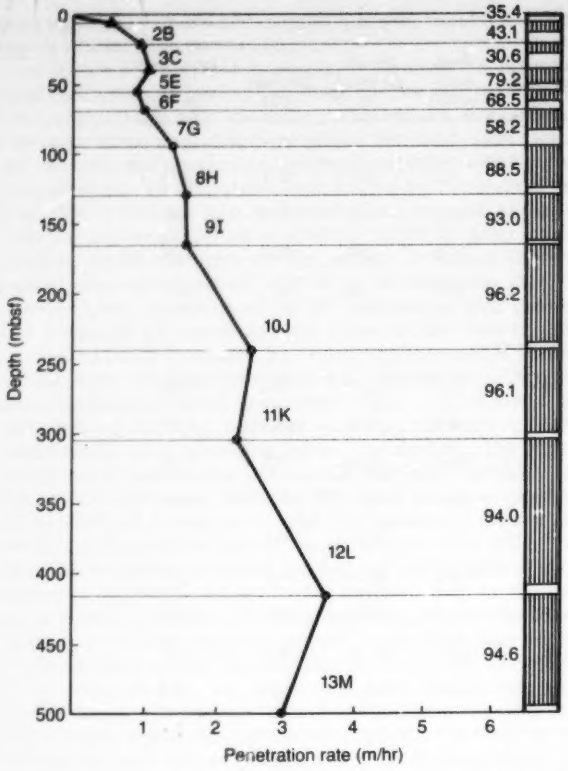

Figure 10. Plot of 9.875-in. core bits run in Hole 735B using type C7 and C57 cutting structure at 60 rpm, 23,000 lb WOB, and 325 gal/min vs. penetration rate. Triangles represent 10.5 × 2.25 in. PDCM coring bit runs; circles indicate 9.875 × 2.25 in. RCB bit runs. 2B, 2C, etc. = bit numbers (see Table 2).

that bit legs do flex. By mounting strain gauges on the bit cone legs and by applying gradually increasing loads to a bit (up to 70,000 lb), it may be possible to determine whether and to what extent the legs are flexing. Depending on the outcome of testing, bit design can be modified as required. It also may be feasible to increase the number of insets in the nose rows to improve wear characteristics of bits in hard-rock formations. One should also consider modifying the lower end of the stabilizer pads to enable the wear-pad edge (oriented down) to trim the hole. This might be accomplished using some type of diamond-hard facing material.

## DEPLOYMENT OF THE NAVIDRILL

### Assembly

The upper, middle, and lower sections of the navidrill coring system (NCB) were assembled and readied for use during Leg 118 (Fig. 11). The navidrill is run in on the wireline or allowed to fall freely down the drill pipe and landed in the BHA (Fig. 12). A flow rate is established (approximately 30 gal/min) down the drill pipe that unlatches the NCB assembly, allowing it to enter the open hole. This flow rate is increased to 80 to 120 gal/min, which rotates the drill motor. This in turn rotates the core-barrel assembly (Fig. 13). Attached to the core barrel is a diamond coring assembly (3.75-in. outside diameter × 2.25-in. inside diameter). As the core barrel advances in the open hole (up to 3.65 m [12 ft]), the core enters the core barrel. After cutting the core, the NCB coring assembly is retrieved by wireline, completing the navidrill coring sequence. Before Leg 118, the navidrill coring system (NCB) was redesigned and new parts were manufactured in Celle, West Germany, by Eastman Christensen Co. The NCB was then tested at the Institute of Petroleum Engineering (ITE) in Clausthal, West Germany. The NCB was tested and evaluated under actual downhole drilling conditions at ITE with good results.

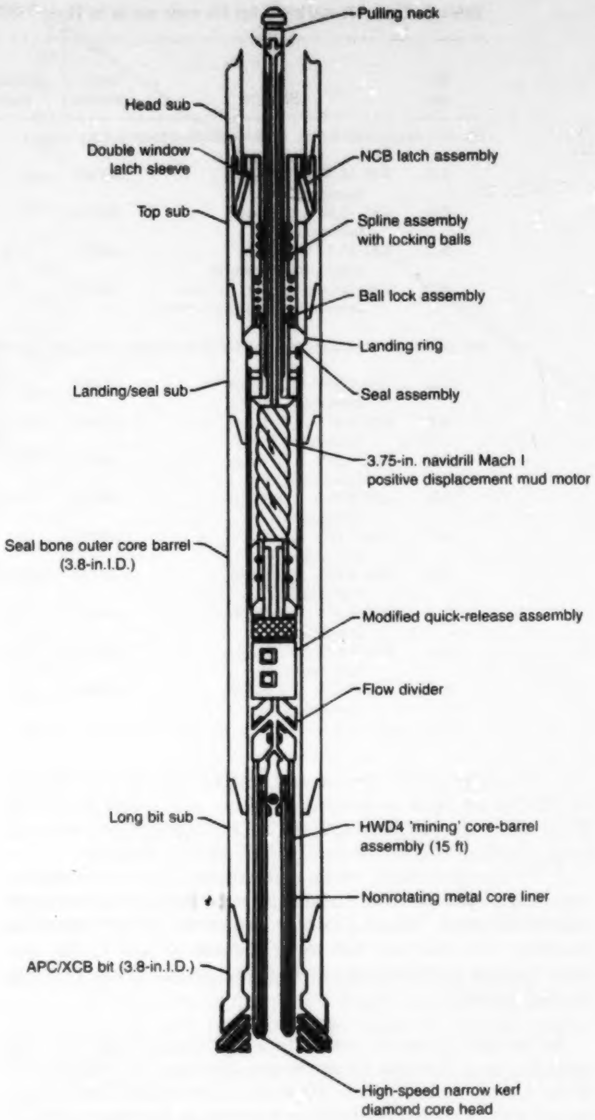
Pulling neck
Head sub
Double window latch sleeve
NCB latch assembly
Top sub
Spline assembly with locking balls
Ball lock assembly
Landing ring
Seal assembly
Landing/seal sub
3.75-in. navidrill Mach I positive displacement mud motor
Seal bone outer core barrel (3.8-in.I.D.)
Modified quick-release assembly
Flow divider
Long bit sub
HWD4 'mining' core-barrel assembly (15 ft)
Nonrotating metal core liner
APC/XCB bit (3.8-in.I.D.)
High-speed narrow kerf diamond core head

Figure 11. Diagram of the 3.75-in. navidrill core barrel.

For Leg 118, the upper section was assembled with a new steel male spline. The NCB version tested during Leg 114 had a brass male spline. The failure of this spline during Leg 114 caused us to build a new high-strength steel male spline for Leg 118. These new male splines were coated with Teflon to reduce the friction between the male and female splines sliding on contact surfaces. Removal of the Teflon coating after testing alleviated the clearance problem that prevented installation of the female spline onto the male spline in Germany. The female spline

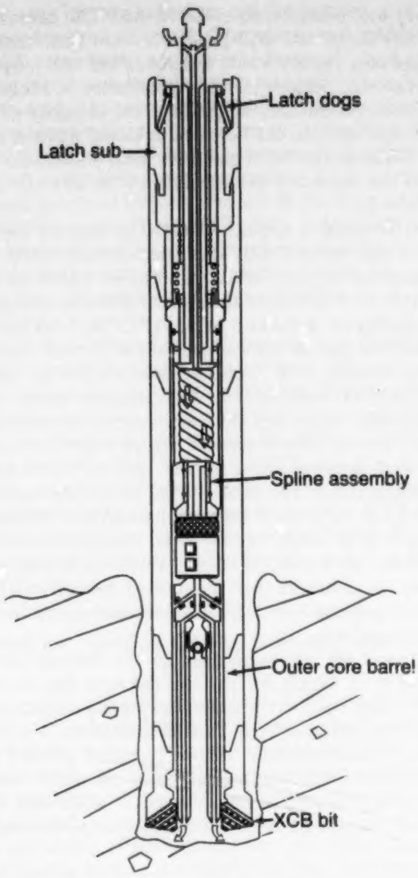

Figure 12. Diagram showing operational sequence when deploying the navidrill core barrel. Sequence of events is as follows: (1) Land NCB in outer core-barrel assembly; (2) Place XCB bit on bottom and circulate to determine beginning flow and pressure parameters; (3) Lock spline assembly in up position and engage NCB latch deep in latch sub.

slid freely over the entire length of the spline before installation of the thruster adapter. A new quick-release assembly compatible with the Leg 118 flow divider was used. Several earlier versions of the NCB were deployed during Legs 104 and 114. After each deployment, we modified the flow diverter and latch system in an effort to improve performance of the tool.

The lower core-barrel section was assembled with an antijamming system, a short breakoff sub, and a slip-type core catcher. The flow divider was jetted with two 0.344- and one 20/32-in. nozzles. The thruster nozzle was jetted with both 0.344- and 10/32-in. nozzles. We selected this nozzle configuration to provide adequate thrust for drilling the rock type encountered in Hole 735B, where the first test was conducted.

We used a Christensen hard-formation impregnated bit. This bit had a square crown and was classified as a soft matrix bit. A soft matrix allows the diamonds on the bit to be abraded at a moderate rate, thereby exposing new, sharp diamonds to continue aggressively cutting the hard, abrasive gabbro. Because of the excellent core recovery we experienced when using the conventional RCB system and because no cores jammed, we did not run a core liner.

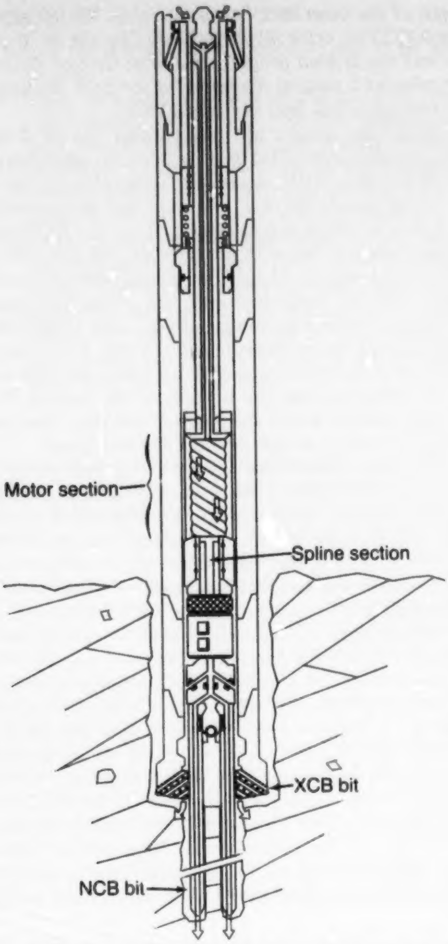

Figure 13. Diagram of the navidrill core-barrel operational sequence when coring ahead. Sequence of events: (1) Using circulation pressure, disengage locking balls on spline assembly; (2) Increase flow rate to produce desired WOB; (3) Monitor flow and pressure parameters while coring. A constant high pressure probably indicates motor stall. A constant low pressure probably indicates core block; (4) NCB system penetrates ahead of XCB bit as coring begins.

## Navidrill Deck Test

A standard advanced piston corer/extended core-barrel (APC/XCB) assembly with one 8.24-in. drill collar was made up and hung off the rig floor. A standard long top sub was run instead of the special top subs having reduced bore that are manufactured in Germany. This was done in case we had to recover a sample using the APC should adequate sediment cover be encountered in subsequent navidrill coring operations outside Hole 735B.

First, we conducted a space-out test, which is a dimensional check to insure that the NCB coring assembly fits properly in the outer core-barrel assembly. Then, the NCB assembly was run into the outer core-barrel assembly and landed in place with the new Christensen delivery system. The space-out measurement for the NCB core was 2.406 in., not the required 3.031 in. This 0.625-in. error was attributed to tolerance problems with the length of the outer core-barrel assembly. We initially thought that the 0.6250-in. error might indicate that the NCB coring assembly was not landed properly in the outer core-barrel assembly. We selected a natural diamond bit for deck drilling because the cement test block had not cured fully.

We placed the cement test block under the NCB BHA and applied approximately 6000 lb of weight. We established a flow rate of 30 gal/min, with no pressure indication on the rig-floor gauge. We increased the flow rate to 40 gal/min, at which time the bit began to rotate and to extend out as the NCB unlatched. At 45 gal/min, we noted a pressure of 350 psi. We then increased the flow rate to 50 gal/min; visual inspection confirmed that the NCB had unlatched and was coring the cement test block. Pressure increased continually at a moderate rate during the 3 min it took to cut through the cement. The indicated surface pressure at this point was 2500 psi and it was still increasing as the bit broke through the bottom of the cement block. We had to stop rotation before the pressure stabilized because of the short time it took us to cut through the test block.

The NCB was pulled from the outer core barrel and laid out. We encountered difficulty when rescoping and relatching the thruster adapter-ball latch system. Some evidence of galling on the male spline could be seen, but damage was considered minimal. While relatching this tool, compression in the springs on the female spline was suddenly released, we heard a noise like a gun discharging. The springs may have been compressed almost to their solid height. The dampening cylinder O-ring was checked and found to be in good condition. We redressed the lower core-barrel section with the hard-formation impregnated bit.

We checked the spacing with the new impregnated bit before running the NCB in the hole. We found that instead of passing through the end of the bit, the NCB was resting on top of the XCB float-valve spacer ring. The spacer ring has a 0.375-in.-diameter bore, while the outside diameter of the NCB bit is 3.75 in. The square crown on the impregnated bit has a maximum of 0.0625-in. × 45° chamfer on the edge of the crown. The 0.050-in. minimal clearance in the spacer ring, coupled with the square crown profile, caused the NCB bit to hang up in the bit sub.

We removed the dummy bit and the spacer ring. This ring bore was machined to 4.05 in. and a 30° chamfer was machined out to 4.3 in. We rechecked the space out with the modified spacer ring. The space out measured exactly 3.03125-in., as specified. We removed the NCB from the outer core barrel and relanded it. The space out then was checked again; it again measured 3.03125-in. No problems were encountered with the NCB bit hanging up in the bit throat after the spacer ring was modified. The natural diamond bit used for the cement drilling test had a more rounded crown, which allowed it to guide itself into the spacer ring more easily than the square-crowned NCB design. The 0.625-in. space-out error noted with the natural diamond bit during the first space-out test was attributed to the tight clearance in the spacer ring, rather than a problem with the dimensions of the APC/XCB outer core-barrel assembly, as we originally thought. Difficulties encountered during earlier legs, such as not being able to establish rotation with the navidrill downhole, may have been associated with the problem of the spacer ring clearance.

## Deployment of the Navidrill in Hole 735B

After completing the deck test, the NCB outer core-barrel system was run to the seafloor. The Eastman Christensen delivery tool was tested with the dummy bit positioned 30 m above the seafloor before reentering the HRGB. The purpose of the test was to determine whether there would be any problems if the delivery tool prematurely released the NCB, causing the tool to fall freely down the drill pipe. We were confident that the NCB dampening system would decelerate the tool properly when landed. However, because of the significance of Hole 735B, we took extensive precautions to preserve the integrity of the hole. The NCB was run into the hole and released without problems. After we retrieved the NCB assembly with a standard overshot, Hole 735B was reentered and the dummy bit was run to the bottom of the hole.

We had to build a special APC/XCB dummy bit that was compatible with the 9.875-in.-diameter of Hole 735B. Both the 11 7/16- and the 10.5-in. APC/XCB bits on board the ship were incompatible with this hole size. The NCB was designed to be deployed during or at the end of an APC/XCB bit run in a single-bit hole. We had to cut a maximum of 5 m of core with the NCB in the bottom of the hole. Because we did not have to advance the large bit and the hole was extremely clean, we used a dummy bit that would maintain the proper spacing above the bottom of the hole. The cones and legs of a used 10.5-in. APC/XCB bit were removed, and in their places, five landing feet were welded in place. The exact overall height and space-out relationships of an APC/XCB bit were maintained. We had planned to run 25,000 lb of weight on bit. After completing construction of the dummy, we decided that only 15,000 lb should be run on the dummy bit to ensure that the welded feet did not come off and possibly jam the hole. The finished dummy bit had an outside diameter of 9 in.

The dummy bit was positioned in the bottom of the hole with 15,000 lb of weight on bit, and the hole was conditioned. Two 25-bbl, high-viscosity mud sweeps were pumped, separated by a 100-bbl saltwater sweep. This was followed by a volume of seawater five times the hole volume pumped at 1000 gal/min. After conditioning the hole, we picked up the bit off the bottom and ran the NCB coring assembly in on wireline with the delivery tool. An account of the NCB coring run performed in Hole 735B follows.

| Time | Action |
|---|---|
| 1835 | Broke circulation, 50 gal/min; no indicated pressure at the surface. |
| 1838 | Increased flow rate to 100 gal/min; 700 psi indicated surface pressure; pressure gradually increased. |
| 1840 | Increased flow rate to 150 gal/min; indicated surface pressure of 2500 psi; 15,000 lb weight on bit. Surface pressure stabilizing. NCB was coring. |
| 1842 | Maintained 150 gal/min; 2300 psi surface pressure; 15,000 lb weight on bit. |
| 1845 | Increased weight on bit to 20,000 lb. Concern that bit may possibly be heaving off the bottom of the hole, as evidenced by the surface pressure fluctuations observed. |
| 1850 | With heave compensator, adjusted weight on bit to 10,000–15,000 lb. |
| 1855 | Sudden increase in pressure to 2800 psi. |
| 1900 | Suspected motor stall or possibly cut full-length core; pressure increased, caused by thruster nozzle entering choke sub. Adjusted weight on bit to 8,000 to 10,000 lb. Pressure decreased to 2500 psi. |
| 1905 | Maintained 150 gal/min; surface pressure, 2450 psi; 12,000 lb weight on bit., Stopped rotation and pulled bit up off the bottom. Had 20,000 lb overpull; possible indication of a core break. Actual coring time, 1840 to 1905 hr (i.e., 25 min of rotation). |

The dummy bit was pulled up off the bottom, and the NCB coring assembly was retrieved. The upper and middle sections of the NCB were kept together and hung off in the handling shuck. The lower core-barrel section was laid out, and the NCB bit was removed. The core barrel contained 0.7 m of gabbro, the longest continuous piece of unbroken core recovered from Hole 735B. The bit crown was severely damaged, possibly by (1) a core stub left in the hole from the previous RCB bit run, (2) one or two small pieces of broken core left in the hole, or (3) several carbide buttons lost off the RCB bits. The inside of the bit crown was worn (some beveling) heavily toward the center of the bit, possibly by the core stub. The water courses also were worn away and were plugged. The diamonds on the bit face had not been polished.

We decided to suspend coring operations in Hole 735B in an effort to preserve the integrity of the hole. We were concerned that the core barrel or bit crown might possibly have been left in the hole because of not being able to run an adequate amount of weight on the dummy bit to keep the BHA motionless in the bottom of the hole. Had we been able to cut a second core in Hole 735B, we might have had better results. The improved geometry in the bottom of the hole (absence of RCB core stub) and grinding up of core fragments on the first NCB coring run might have provided considerably better conditions for continued NCB coring.

### Unsupported Spud-in Coring Attempt with the NCB, Hole 735C

After tripping the pipe out of Hole 735B, we planned to run the NCB back in the drill pipe by wireline using the delivery tool and to try to cut a core using an unsupported BHA. We recognized that testing the NCB using an unsupported BHA was not the ideal situation. However, the information that could be gained from such a test would be of great benefit when assessing the capabilities of performing shallow exploratory coring in a manner similar to that done with PDCMs. Another contributing factor in this decision was that there was not enough time to relocate the ship to an area where sediment cover was present.

Had the first unsupported coring attempt been successful, a second coring run would have been made with the unsupported BHA after allowing the NCB system to fall freely to the seafloor. While running the NCB in on the wireline, we saw that the wireline weight indicated that the tool was floating somewhat. This meant that the check ball installed on top of the PDCM was forcing the fluid inside the drill pipe to flow around the NCB assembly and was producing a significant braking effect on the system. We felt this evidence justified our conducting a free-fall test in open water.

Before running the NCB in on the wireline, we encountered significantly more difficulty when relatching the thruster adapter-ball latch assembly. We had to drop the upper and middle sections of the NCB repeatedly in the handling shuck on a tugger line for the tool to relatch. We noted damage on the spline corners where the balls ride (Fig. 11). Again, after we finally did relatch the NCB as the springs expanded, we heard what sounded like a gunshot.

The NCB was run in on wireline and delivered again without difficulty. The area in the vicinity of the beacon was covered with a thin layer of sediment. The bit was lowered to the bottom and 15,000 lb of weight was placed on it. Sediment cover was no more than 5 cm thick; we presumed that the underlying rock was gabbro. An account of the unsupported NCB coring run in Hole 735C is given below.

| Time | Action |
|---|---|
| 2315 | Tagged the seafloor and applied 15,000 lb of weight to the bit. |
| 2318 | Brought flow rate up slowly to 150 gal/min, indicated surface pressure of 2700 psi. Readjusted, pump to 140 gal/min, surface pressure of 2400 psi. Observed dummy bit rotating on the bottom and reactive torque in the drill pipe back to the surface. Locked top drive brake to counter reactive torque. |
| 2325 | Decreased flow rate to 135 gal/min; surface pressure 2400 psi, with occasional spike to 3000 psi. Suspected motor stall associated with BHA motion. |
| 2328 | Observed bit pumped off bottom and NCB core-barrel bending. Ceased NCB coring immediately and tripped pipe out of hole with the NCB in outer core-barrel assembly. |

To free the NCB coring assembly (Fig. 11), we had to cut the core barrel in three places. The core barrel was bent about 1 m from the NCB bit, and was slightly bent for two-thirds of the entire barrel length. We encountered extreme difficulty when extending the spline out to remove the core barrel. When the core barrel extended out onto the seafloor, significant galling occurred. After removing the lower and upper sections from the outer core barrel, we tried to relatch the thruster adapter-ball latch assembly. After we worked the female spline onto the thruster adapter, the assembly jammed. The ball ports in the female spline were 0.5 in. from the ball groove in the thruster adapter when the latch system jammed. We had to cut the landing and dampening sleeves off the female spline to release compression on the balls and thruster adapter shaft. No grit or sand was found inside the system. The springs remained loaded until we cut into the sleeve. Inspection of the male spline revealed significant galling along the corners of the spline where the balls make contact. The female spline would no longer slide along the male spline unless we applied excessive force with tuggers.

### Evaluation of Mechanical Design

The inherent design of the ball-latch groove forced the balls to drag or load up against the thruster adapter and splines. The more load that is applied, the greater the wedging or jamming force generated. By reducing the ball size and modifying the angle of the ball groove, it may be possible to correct these problems. However, alternative latch systems should also be explored. The travel length of the dampening system should be increased from 2 in. to 8 to 12 in. This will add a margin for error to the hydraulic system, which now must be finely balanced and has no margin for error. Ideally, the dampening and latching functions should not be separated. If this is not practical, then having adequate distance to perform both functions with some over-traveling built into the dampening system will greatly improve its reliability.

The middle and lower sections of the NCB are mechanically sound. Reducing the number of components to simplify assembly and inventory of parts on the rig should be tried. It might be possible to combine two or more components into a single part. For example, the female quick-release and flow divider could be made as one unit. The number of variable pressure decreases in the NCB hydraulic system should also be reduced. This will benefit the prediction and understanding of downhole operating characteristics of the NCB.

## OBSERVATIONS AND CONCLUSIONS

1. When the NCB stalls out, the increased pressure was observed to be significantly higher (by up to 25%) than theoretical values. This increased pressure can cause the navidrill to scope out ahead of the APC/XCB bit with sufficient force to pick the BHA off the bottom when light bit weights are run (either inside a hole or during an unsupported spudding attempt).

2. Most likely, the NCB pulled the bit off the bottom in both Holes 735B and 735C. We deduced this from similar surface-pump pressure readings that were observed during the two NCB coring runs and by examining the core recovered from Hole 735B, which is slightly "S"-shaped. The gauge hole prevented the core barrel from being bent when the core barrel stroked out for short periods of time.

3. As shown by both the reactive torque in the drill pipe (observed at the surface) and the thrust exerted against the BHA, the navidrill system, when seated properly, is capable of generating more than ample torque for coring rock types such as gabbro.

4. Based on the significant amount of reactive torque and thrust observed during the unsupported spudding attempt, the use of a high-speed, low-torque motor and/or larger size nozzle should be considered.

5. To prevent the NCB from pulling the bit off the bottom, more than 20,000 lb of weight should be maintained on the bit, then adjusted to higher levels as heaving of the ship dictates.

6. To further promote BHA stability during future deployment of the NCB, both near-bit and string stabilizers should be considered, especially in the 11.4375-in.-diameter holes.

7. The navidrill coring system has been shown to be capable of cutting a high-quality undisturbed core in an extremely hard, dense formation, such as gabbro.

8. The navidrill coring system indicates that high-speed mining systems have definite potential in floating vessel hard-rock applications.

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Shipboard Scientific Parties, 1988. Site 648. *In* Detrick, R., Honnorez, J., Bryan, W. B., Juteau, T., et al., *Proc. ODP, Init. Repts.*, 106/109: College Station, TX (Ocean Drilling Program), 35-134.

**Date of initial receipt: 9 August 1988**
**Date of acceptance: 9 August 1988**
**Ms 118A-108**

# SECTION 2: SITE REPORTS

# 3. SITE 732[1]

## Shipboard Scientific Party[2]

### HOLE 732A

**Date occupied:** 25 October 1987

**Date departed:** 27 October 1987

**Time on hole:** 54 hr

**Position:** 32°32.81′S, 57°03.289′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4893.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4881.9

**Total depth (rig floor, m):** 4896.00

**Penetration (m):** 3.00

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 3.00

**Total core recovered (m):** 0.01

**Core recovery (%):** 0.3

**Hard rock:**
Depth (mbsf): not known
Nature: Mylonitized serpentinite

### HOLE 732B

**Date occupied:** 27 October 1987

**Date departed:** 28 October 1987

**Time on hole:** 10 hr

**Position:** 32°32.81′S, 57°03.289′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4889.4

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4878.3

**Total depth (rig floor, m):** 4897.40

**Penetration (m):** 8.00

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 8.00

**Total core recovered (m):** 1.90

**Core recovery (%):** 23.8

**Oldest sediment cored:**
Depth (mbsf): 1.35
Nature: Volcanic sand/gravel, muddy siliceous ooze, and clasts of oceanic rocks
Earliest age: Holocene

**Hard rock:**
Depth (mbsf): not known
Nature: Clasts of oceanic rocks

### HOLE 732C

**Date occupied:** 28 October 1987

**Date departed:** 29 October 1987

**Time on hole:** 24 hr

**Position:** 32°32.81′S, 57°03.289′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4896.5

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4885.4

**Total depth (rig floor, m):** 4920.50

**Penetration (m):** 24.00

**Number of cores (including cores with no recovery):** 3

**Total length of cored section (m):** 29.00

**Total core recovered (m):** 0.70

**Core recovery (%):** 2.4

**Hard rock:**
Depth (mbsf): not known
Nature: Basalt, gabbro, and lithic sandstone rubble

### HOLE 732D

**Date occupied:** 29 October 1987

**Date departed:** 30 October 1987

**Time on hole:** 22 hr 45 min

**Position:** 32°32.85′S, 57°02.70′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4821.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4809.9

**Total depth (rig floor, m):** 4832.00

**Penetration (m):** 11.00

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 6.00

**Total core recovered (m):** 0.31

**Core recovery (%):** 5.2

**Hard Rock:**
Depth (mbsf): not known
Nature: Basalt, diabase, gabbro, and peridotite rubble

### HOLE 732E

**Date occupied:** 30 October 1987

**Date departed:** 30 October 1987

**Time on hole:** 14 hr 45 min

**Position:** 32°32.85′S, 57°02.70′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4819.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4807.9

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in List of Participants preceding the contents.

**Total depth (rig floor, m):** 4826.00

**Penetration (m):** 7.00

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 7.00

**Total core recovered (m):** 0.18

**Core recovery (%):** 2.6

**Hard Rock:**
Depth (mbsf): 5.00
Nature: Basalt and diabase rubble

## HOLE 732F

**Date occupied:** 30 October 1987

**Date departed:** 31 October 1987

**Time on hole:** 16 hr 30 min

**Position:** 32°32.85′S, 57°02.70′E

**Bottom felt (rig floor; m, drill pipe measurement):** 4818.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4806.9

**Total depth (rig floor, m):** 4833.80

**Penetration (m):** 15.80

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 15.80

**Total core recovered (m):** 0.30

**Core recovery (%):** 1.9

**Hard rock:**
Depth (mbsf): not known
Nature: Basalt and diabase rubble

**Principal results:** Site 732 is located on a median tectonic ridge that bisects the northern half of the north-south trending Atlantis II Transform in the Indian Ocean. Using dredge hauls from the wall of this ridge, we recovered mainly serpentinized peridotite, which suggests that the feature is a mantle diapir. The principal scientific objectives for drilling this site were (1) to determine the nature and vertical variability of rock in the median ridge, (2) to investigate the deformation of mantle rocks on the floor of the transform, (3) to determine the thermal structure of the mantle section and assess the extent of hydrothermal alteration, and (4) to determine the physical properties, magnetism, and seismic velocities of mantle rock. To achieve these objectives, we planned to drill a deep reentry hole at this site using the bare-rock guidebase.

*JOIDES Resolution* arrived at Site 732 at 1030 hr on 25 October 1987. We conducted a 26-hr television/sonar survey to locate areas for test spud-in and for possible guidebase deployment. The survey revealed a relatively flat, sedimented surface on top of the ridge, with some areas of rock outcrop and boulders on steep, probably faulted, flank slopes.

Six test holes were drilled in two locations at Site 732: Holes 732A through 732C at 32°32.81′S, 57°03.289′E in 4878.3 to 4885.4 m of water, determined as pipe length from rig floor minus 11.1 m (distance between the rig floor and sea level) near the break of slope, and Holes 732D through 732F at 32°32.85′S, 57°02.7′E in 4806.9 m to 4809.9 m of water nearer the ridge crest. The deepest penetration was 24 meters below seafloor (mbsf) in Hole 732C. We recovered a total of 3.51 m of material that consisted entirely of unconsolidated lithic gravel interlayered with indurated sandstone and poorly consolidated sand and muddy siliceous ooze. The siliceous ooze consists of about 60% siliceous microfossils, 35% clay, and 5% broken foraminifers. Most of the unconsolidated sand consists of volcanic detritus, including rock fragments, plagioclase, and pyroxene; the remaining part is composed of broken foraminifers and siliceous debris.

Pebbles and cobbles in the gravel range from less than 1 cm to 6 cm in maximum dimension and are subangular in shape. They consist of plagioclase phyric basalt, aphyric basalt, metabasalt, diabase, greenstone, pyroxene gabbro, metagabbro, ferrogabbro, serpentinite, serpentinized peridotite, mylonite, amphibolite, and sedimentary rock. Basalt and diabase are the most common of the recovered clasts. The clasts of sedimentary rock are small fragments of well-sorted, medium- to coarse-grained, reddish sandstone. One clast grades in size from medium to fine sand. The sand grains are angular and consist of diverse lithic and mineral fragments.

Calcareous nannofossils from the recovered sediments indicate an age of mid-Pleistocene, probably between 0.27 and 0.46 m.y. (Zone NN20). Rare specimens of reworked Miocene and Pliocene species also are present

Drilling operations at Site 732 suggest that each hole penetrated a few (2-8) meters of soft material overlying a harder unit. Thus, the ridge appears to be capped by a poorly sorted gravel or conglomerate interlayered with sand and sandstone and overlain by a thin pelagic cover. Clasts from the gravels are similar in size and composition to those recovered from gravels on the floor of the transform during the site survey. These deposits probably were laid down by debris flows and turbidity currents that originated on the steep walls of the transform. The appearance of these basinal sediments on top of the median ridge suggests recent uplift of that feature, either by faulting or by serpentinite intrusion.

Unstable hole conditions made it impossible to reach basement at this site. Consequently, the site was abandoned and the ship moved to Site 733 on the west wall of the transform.

## BACKGROUND AND SCIENTIFIC OBJECTIVES

Fracture zones are ubiquitous features of the oceanic lithosphere, yet little is known about their petrology, structure, or tectonic evolution. Recent models for fracture zones (e.g., Schouten and Klitgord, 1982) suggest that they are relatively cold zones separating stationary spreading-center cells beneath spreading-ridge segments. Crustal magma chambers are believed to lie beneath the spreading cells, with new crust being formed by crystallization on the walls of the magma chambers and by vertical and lateral dike injection along the ridge axis. In this model, less magma will reach the far edges of the spreading cells (i.e., fracture zones), leading to thinner crustal sections. Such thinning of oceanic crust in the vicinity of fracture zones has been demonstrated by seismic studies along several ridge axes (e.g., Detrick and Purdy, 1980; Fox et al., 1980; Cormier et al., 1984). In some cases, the crustal thickness in fracture zones may be less than 5% to 10% of normal sections.

Because of these relatively thin crustal sections and the great topographic relief of many fracture zones, mantle material is commonly exposed on the floors and walls of these zones. The abundance of mantle rocks in fracture zones appears to correlate closely with the spreading rate of the associated ridge. For example, peridotites make up more than 65% of all material dredged from fracture zones of the slow-spreading Southwest Indian Ridge, whereas they make up only 10%-15% of dredge hauls from fracture zones of typical slow-spreading ridges and are nearly absent from those of the fast-spreading East Pacific Rise (H. Dick, unpubl. data). Considering the difficulty of achieving deep penetration in normal oceanic crust, fracture zone drilling provides one of the best possibilities for obtaining *in-situ* samples and stratigraphy of oceanic crust and mantle.

A prime objective of Leg 118 was to penetrate and recover a deep section of mantle peridotite from the floor of the Atlantis II Fracture Zone on the Southwest Indian Ridge. A site survey conducted in October 1986 (*Conrad* cruise 27-09, H. Dick, Chief Scientist) identified a "median tectonic ridge" that bisects the northern half of the transform valley. Seismic profiles failed to locate any sediments on the ridge, and dredge hauls from the ridge flanks yielded chiefly peridotite and lesser amounts of gabbro, basalt, and greenstone. This feature appeared to be a diapiric structure along which mantle peridotite was exposed on the seafloor. Relatively flat topography on the crest of the ridge suggested that a hard-rock guidebase could be successfully deployed and used to drill a deep basement hole. Site 732 is located near the crest of this ridge, where dredge hauls recovered abundant peridotite. Major objectives of the site were as follows:

1. To determine the nature and vertical variability of rock in the median tectonic ridge.
2. To investigate the nature and extent of deformation in mantle rocks beneath the floor of the transform.
3. To determine the thermal structure of the mantle section and to assess the extent of alteration and seawater penetration.
4. To determine the physical properties, magnetism, and seismic velocities of mantle rock beneath the transform floor.

## GEOLOGIC AND TECTONIC SETTING

The Atlantis II Fracture Zone trends nearly north-south and offsets the Southwest Indian Ridge at approximately 57°E (Fig. 1). The transform is about 210 km long and 30–40 km wide, as measured between the slope breaks from normal ridge topography to the steep transform walls. The spreading rate, as determined from the magnetic anomalies mapped east and west of the transform, has been about 10 mm/yr over the last 20 m.y. The magnetic anomalies created since anomaly 5 appear to extend into the transform valley near the inferred modern slip zone (Fig. 2).

Relief on the transform valley is on the order of 5800 m, and the walls of the transform valley are remarkably steep (typically 30°–40°), although locally these may be much more subdued. In detail at some locations, the walls of the transform commonly are scalloped in plan, probably because of extensive slumping and landsliding.

A bathymetrically prominent median tectonic ridge bisects the northern half of the transform valley and can be followed intermittently down the southern half as well (Fig. 3). In the north, this ridge shoals to 4200 m and has relief between 1000 and 1500 m, whereas in the southern half of the valley the relief drops abruptly to only a few hundred meters. From four dredge hauls along the median tectonic ridge chiefly serpentinized peridotite and lesser amounts of gabbro, metamorphosed basalt, and diabase were recovered. Virtually all of the basaltic rocks recovered have been altered, and this alteration was usually oxidative, with many of the rocks stained a bright red or white. In addition, some unusual breccias cemented by a black tarry-appearing hydrothermal oxide were recovered.

The position of the median tectonic ridge suggests that it marks today's slip boundary in the transform. We believe it is composed chiefly of peridotite, perhaps in the form of a mantle diapir. The nature of the altered rocks suggests that the conditions of hydrothermal alteration along the transform plate boundary may differ substantially from those occurring along ocean ridges.

## OPERATIONS

### Port Louis Port Call

Leg 118 commenced in Port Louis, Mauritius, at 0700 hr, 18 October 1987, when *JOIDES Resolution* dropped anchor in the Port Louis harbor. (All times are local ship time unless stated otherwise.) ODP personnel boarded the ship during the morning, the Schlumberger cable was changed, and inspection of the drill pipe began. At 2145 hr on 19 October 1987, the ship shifted to the dock, and fuel and air cargo were taken aboard. During 20 and 21 October 1987, sea freight was loaded on the ship, while surplus equipment was offloaded to make room for the hard-rock guidebase and a large quantity of ancillary hard-rock drilling equipment. By the morning of 22 October 1987, all drill pipe used since the last inspection had been inspected, and the ship got under way at 1200 hr on 22 October 1987.

### Approach to Site 732

The general location for Site 732 was selected on the median ridge of the Atlantis II Transform (Fig. 3), based on contoured Sea Beam bathymetric maps and a dredge haul that recovered peridotite almost exclusively. A small area at this location was selected for detailed surveying before dropping the beacon. The track of the ship from Mauritius was planned to minimize the time necessary to reach that location.

The voyage to the median ridge was uneventful, and at 0900 hr on 25 October 1987 the ship slowed to begin the site survey. A voyage of 771 nmi was made in 71.5 hr at an average speed of 10.8 kt. We planned for an initial brief survey to establish the exact location of the Sea Beam bathymetric contours using the global positioning system (GPS) navigating equipment aboard the ship. Although the Sea Beam mapping had also been controlled by GPS and transit satellite navigation, we thought that parts of track lines between navigation control might be off the location by 1 to 2 nmi.

The final track lines of the echo sounding survey (Fig. 4) closely reproduced the planned track, which was designed based on trends of the Sea Beam contours. We planned for the beacon to be located directly upslope of the dredge haul on the east flank of the median ridge, and the track lines were laid out to cross in nearly orthogonal direction to the north-south trending depth contours of the median ridge. The survey lines extended from the adjacent eastern basin floor across the crest of the ridge. Because the depth contours were strongly aligned in a north-south direction, control of contour location was best in the east-west direction. Fortunately, the ship arrived for the beacon survey during GPS coverage, which resulted in an efficient survey. The depths expected from the Sea Beam maps were well reproduced along the ship's track. Apparently, the map contours were accurately located in this region, at least in the east-west direction.

Although the ship's standard echo sounders (12 and 3.5 kHz) were operated, very little data were recorded at normal ship speed (10 to 12 kt) because of the high background noise of the ship. Hence, the ship was slowed to about 6 kt before arriving at the first turning point of the survey. The most useful recordings (Fig. 5) were obtained with the seismic profiling system (single channel, water-gun source) towed astern. The beacon was dropped at the end of the survey (1030 hr, 25 October 1987), based on the planned GPS location, and landed just east of the median ridge summit at 32°32.75′S, 57°03.10′E at a water depth of about 4800 m.

### Television/Sonar Survey

After dropping the beacon, we began a survey with the television/sonar system suspended on the coaxial cable through the moon pool (without pipe). Offsets of the ship from the bottom beacon and from a beacon on the camera frame were recorded during the survey and used to calculate the offsets of the camera from the bottom reference beacon (Fig. 6). Visual impressions of the bottom character recorded on videotape and in writing were used to prepare an annotated map of relevant features on the seafloor. The amount of wire played out was also recorded as an indication of depth, and a ball 0.3 m in diameter was suspended about 10 m below the camera frame to provide a useful scale for bottom features and to indicate height above bottom to the winch operator.

The survey lines were run in an "E" pattern, with one irregular north-south profile nearly 4 km long near the crest of the ridge and three other profiles intersecting it orthogonally (each about 2 km long) down the east slope. Survey tracks were run downslope where appropriate to avoid catching the camera frame on cliffs or large boulders. The survey was performed from

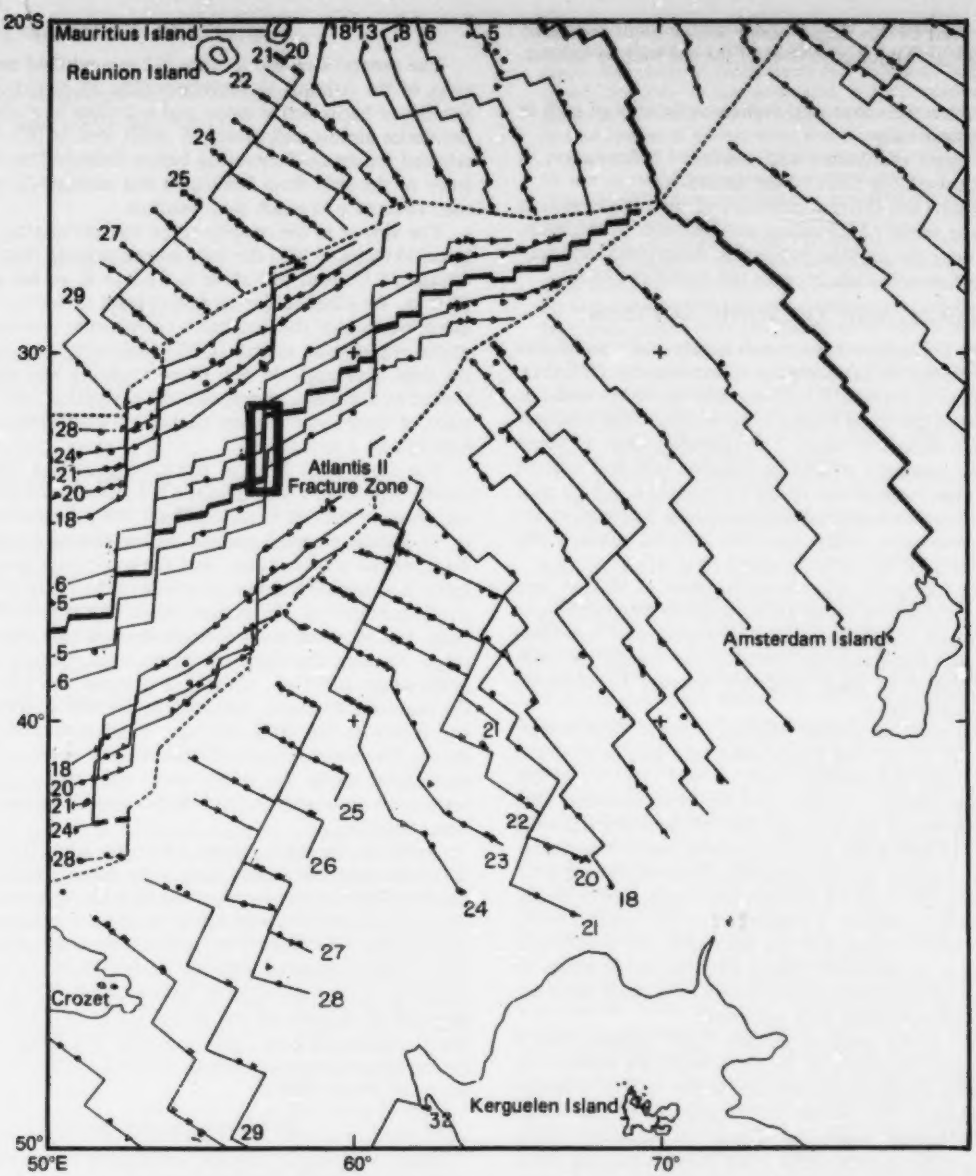
20°S
Mauritius Island
Reunion Island
18
13
8
6
5
21
20
22
24
25
27
29
30°
28
24
21
20
18
6
5
5
6
Atlantis II Fracture Zone
40°
18
20
21
24
28
25
26
27
28
21
22
23
24
20
18
21
Amsterdam Island
Crozet
Kerguelen Island
32
29
50°
50°E
60°
70°

Figure 1. Atlantis II Fracture Zone within the plate tectonic configuration of the Southwest Indian Ocean. Magnetic anomalies after Patriat et al. (in press). Dashed line indicates past plate boundaries. Heavy box shows location of Figure 2.

about 1345 UTC, 25 October, to 1130 UTC, 26 October (22 hr 45 min); altogether, the survey lasted about 1.5 days, including preparation of the instruments and a round trip to the seafloor. Geometric constraints of the winch location over the moon pool required that the ship move only in reverse direction at speeds of 1/2 to 2/3 kt.

Results showed that most of the median ridge is covered with sediment and/or rubble of unknown thickness, with a few large blocks or boulders (one to several meters in dimensions) on or near steep slopes. We had difficulty determining whether some of the larger sized material was outcrop or had been displaced. Two sites within the survey region were selected for spud-in attempts; each site sloped less than 20° and was large enough for guidebase deployment. One site was 500 m due east of the beacon (32°32.8′S, 57°03.3′E) and the other, 400 m west of the beacon (32°32.9′S, 57°02.7′E) near the crest of the ridge. The former site was located directly above a probable outcrop on the middle downslope profile, and the latter near the crest of the ridge where gravitational accumulation of rubble from above would not be expected.

## Hole 732A

The operational plan was to test drill the site before committing the hard-rock guidebase. Test drilling should determine whether a hole could be started in hard rock using an unsupported bottom-hole assembly (BHA). The BHA consisted of a 10½ in. bit (RBI C4), crossover sub, a coring motor, five 8¼ in. drill collars, crossover sub, one 7¼ in. drill collar, and six stands of 5¼ in. drill pipe.

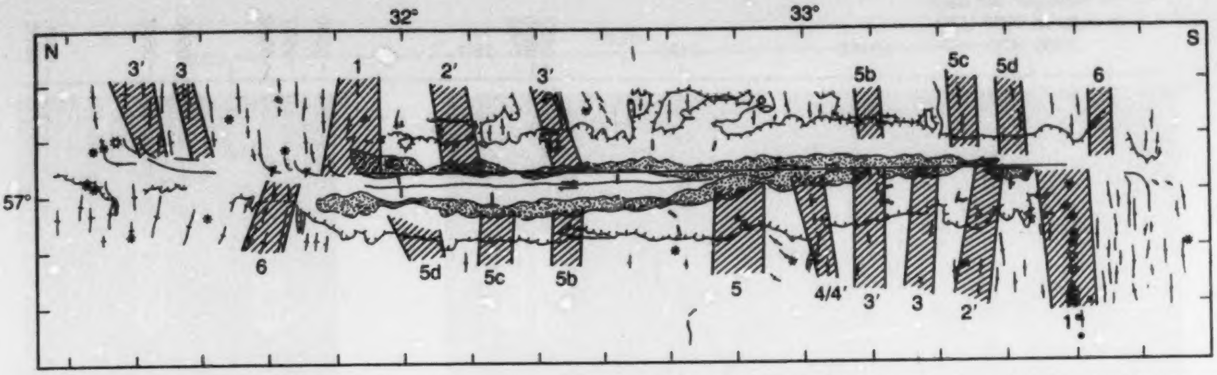
32°
33°
N
S
57°
3'
3
1
2'
3'
5b
5c
5d
6
6
5d
5c
5b
5
4/4'
3'
3
2'
1

Figure 2. Tectonic map of the Atlantis II Fracture Zone (after Dick et al., unpubl. data). Hatched linear zones are preliminary magnetic anomaly identifications. Short lines and circles are rock dredge locations. Arrows highlight dredges consisting predominantly of serpentinized peridotite. Dotted areas denote basins.

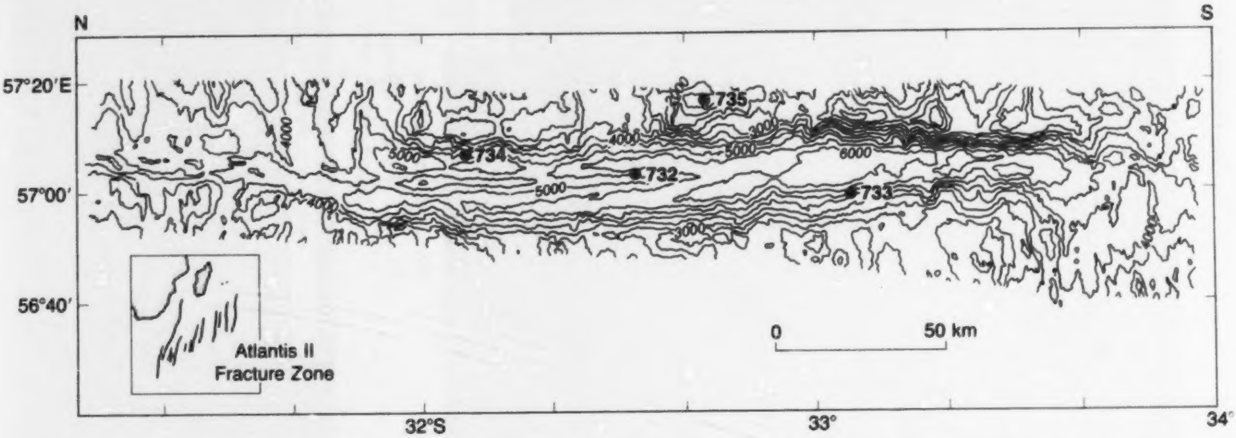
N
S
57°20'E
57°00'
56°40'
4000
5000
734
4000
732
5000
735
3000
5000
6000
733
4000
3000
4000
0
50 km
Atlantis II
Fracture Zone
32°S
33°
34°

Figure 3. Bathymetric map with contours at 500-m intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing Leg 118 drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

32°31'S
32°32'
32°33'
0912
0916
0930
0938
0941
0944
0945
0953
0926
0920
0923
1000
1005
1010
1015
1018
1023
1028
1030
Beacon
Holes
732 D–F
Holes
732 A–C
57°01'E
57°02'
57°03'
57°04'
57°05'
57°06'

Figure 4. Ship track line for deployment of beacon at Site 732. Times noted along the track are local (UTC + 4 hr). Beacon and hole locations are shown.

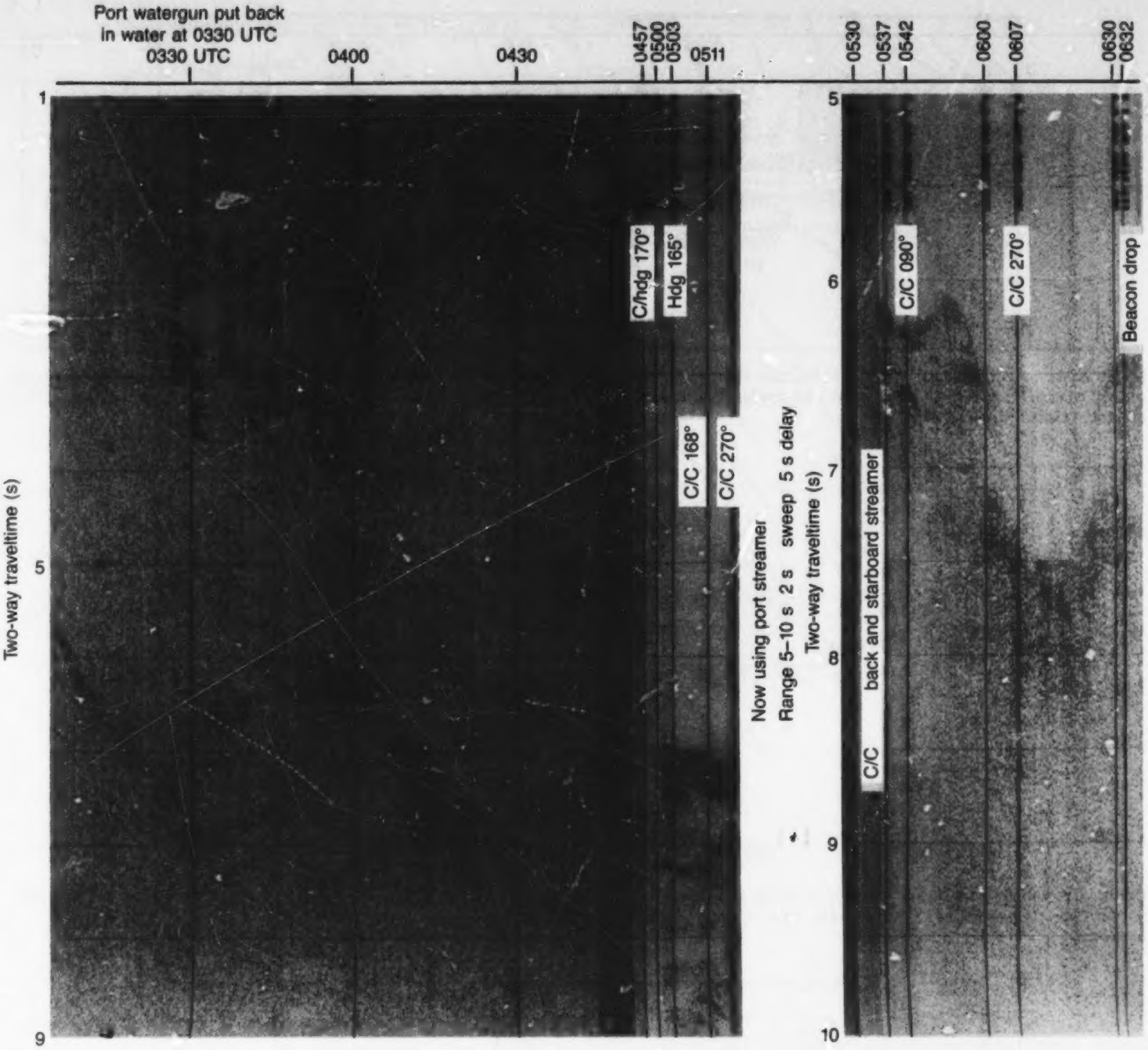

Figure 5. Seismic-reflection system recordings made on the approach to beacon drop at Site 732. Time range of recording after each "shot" initially was 1 to 9 s, later changed to 5 to 10 s. Profile shown was recorded over interval from about 0310 hr to 0630 hr UTC (0710 hr to 1030 hr Local), 25 October 1987.

The water depth calculated by the precision depth recorder (PDR) was of little value because of the extreme variation in the bottom profile. Several reflectors were present, and we concluded that the seafloor was at 4831 or 4794.3 meters below rig floor (mbrf). As the bit approached bottom it was followed by the television/sonar. The seafloor was tagged at 4893 mbrf.

The hole was cored from 4893 to 4896 mbrf (0–3 mbsf; Table 1), at which point a pressure leak developed in the drill-string weight indicator system. To repair the leak, we had to pull the bit above the seafloor. The core barrel was pulled to the surface, and a fragment of mylonitized serpentinite was recovered.

## Hole 732B

The bit was observed on the television/sonar to penetrate about 5 m of very soft sediment before it began to take weight. The hole was spudded with minimum difficulty, and the mud motor performed very well. The hole was cored from 4889.4 to 4897.4 mbrf (0–8 mbsf; Table 1). At 8 mbsf, we saw that space-out of the bit relative to the hard basement at 5 mbsf would not allow us to connect drill pipe when the bit was below stable formation. The core barrel was removed, and 1.9 m of siliceous ooze and sand was recovered, including clasts of basalt, diabase, gabbro, and serpentinite.

## Hole 732C

The hole was cored from 4896.5 to 4920.5 mbrf (0–24 mbsf; Table 1). When the bit was raised off the bottom to connect drill pipe, the hole collapsed. It was re-drilled to 4916 mbrf (19 mbsf), and several mud slugs were pumped in an effort to stabilize the walls, but more hole was lost. Because we did not know the

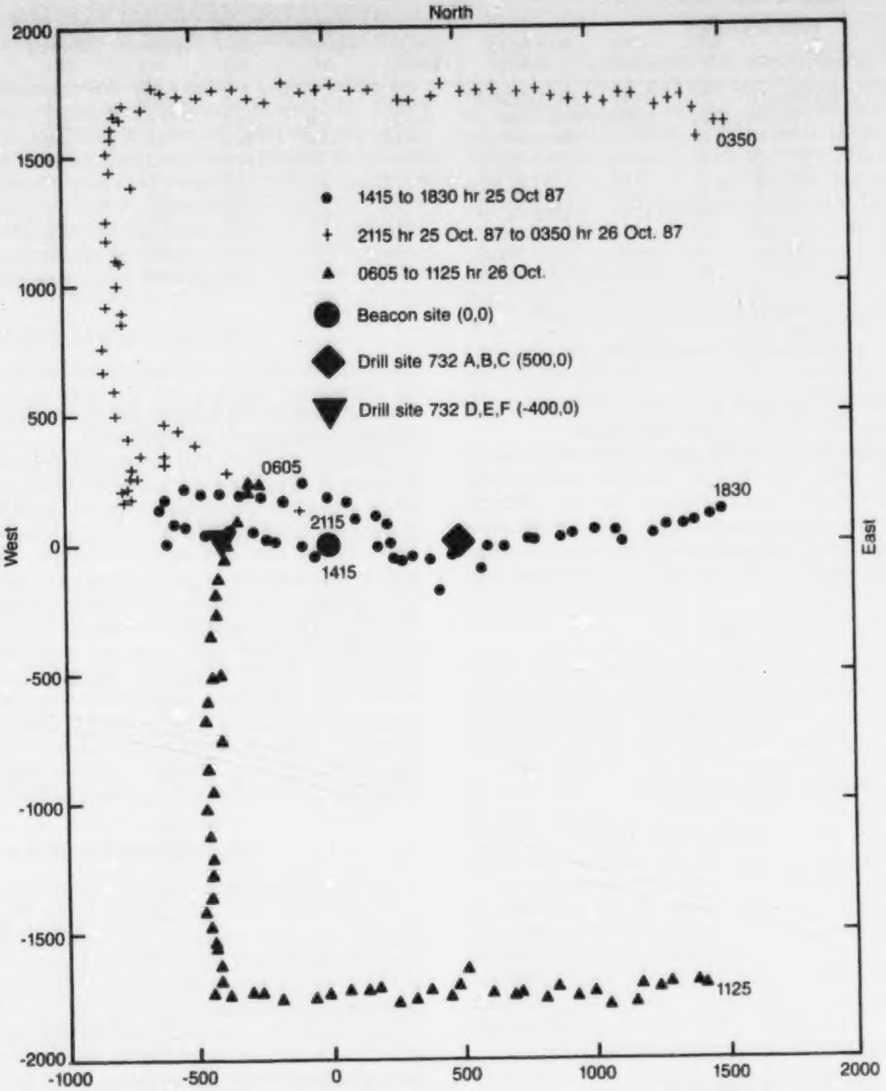

Figure 6. Plot of navigation for TV camera/sonar survey at Site 732. Symbols are positions at nominal 5-min intervals over various time periods (UTC) during survey as indicated. Beacon at origin of plot is located at 32°32.8′S, 57°03.0′E; drill-hole locations also are shown. Axis dimensions in meters from beacon.

thickness of the rubble or the bad caving conditions, we decided that coring at this site was not advisable. A total of 0.7 m of basalt, gabbro, and lithic sandstone rubble was recovered in the core barrel.

### Hole 732D

The ship was moved 900 m due west of Holes 732A, 732B, and 732C, nearer to the top of the ridge, where we thought there would be less rubble. The mud line was located at 4821.0 mbrf by using the television/sonar. The bit pushed through 5 m of soft sediment (Table 1). The hole was stable, but the drilling rate was very slow. It took 5.25 hr to core 6 m to 4832.0 mbrf (11 mbsf), at which time the bit stopped drilling. The drilling rate suggested that the bit was worn out; thus, the pipe was tripped out of the hole. When the bit reached the surface, we were surprised to find that it was in nearly new condition. A total of 0.31 m of rubble composed of basalt, diabase, gabbro, and peridotite was recovered.

### Hole 732E

Because of the presence of the 5-m-thick sediment cover, we concluded that spud-in with a conventional rotary core bit was possible. The advantage of the rotary system is its ruggedness and its relatively low cost compared to that of the mud motor. Not only are mud motors costly, but the only two in existence were on board the ship; their loss due to BHA failure was a concern.

The BHA consisted of the 9⅞ in. bit (an RBI C4), long bit sub, control drill collar, long top sub, head sub, seven 8¼ in. drill collars, crossover sub, one 7¼ in. drill collar, crossover

Table 1. Coring summary for Site 732.

| Core | Date (Oct. 1987) | Time (Local) | Total depth[a] (mbrf) | Depth (mbsf) | Length advanced (m) | Length cored (m) | Length recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| 118-732A-1D | 27 | 17.45 | 4893.0–4896.0 | 0–3.0 | 3.0 | 3.0 | 0.01 | 0.3 |
| 732B-1D | 28 | 01.30 | 4889.4–4897.4 | 0–8.0 | 8.0 | 8.0 | 1.90 | 23.8 |
| 732C-1D | 28 | 08.15 | 4896.5–4910.5 | 0–14.0 | 14.0 | 14.0 | 0.0 | 0.0 |
| 732C-2D | 28 | 17.30 | 4910.5–4920.5 | 14.0–24.0 | 10.0 | 10.0 | 0.35 | 3.5 |
| [b]732C-3D | 28 | 23.00 | 4910.5–4915.5 | 14.0–19.0 | 0.0 | 5.0 | 0.35 | 7.0 |
| 732D-1 | 29 | — | 4821.0–4826.0 | 0–5.0 | 5.0 | 0.0 | 0.0 | — |
| 732D-1D | 29 | 12.30 | 4826.0–4832.0 | 5.0–11.0 | 6.0 | 6.0 | 0.31 | 5.2 |
| 732E-1R | 30 | 14.50 | 4819.0–4826.0 | 0–7.0 | 7.0 | 7.0 | 0.18 | 2.6 |
| 732F-1R | 30 | 20.05 | 4818.0–4833.8 | 0–15.8 | 15.8 | 15.8 | 0.30 | 1.9 |
| [c]732F-2B | 30 | 20.05 | 4818.0–4833.8 | 0–15.8 | 0.0 | 0.0 | 0.01 | — |

[a] Determined as pipe length from rig floor.
[b] Rubble fill.
[c] As fragments recovered from bit; not cored.

sub, and six stands of 5⅓ in. drill pipe. The bottom three drill collars were inspected for cracks; none were found.

The bit took weight at 4819 mbrf, and the hole was cored to 4826 mbrf (7 mbsf; Table 1) in 68 min. The pipe became stuck and required 150,000 lb of overpull to free it, but the combination of pipe stretch and finite response time of the motion compensator caused the pipe to rebound out of the hole. A wireline trip was made for the core barrel, and 0.18 m of basalt and diabase rubble was recovered.

### Hole 732F

The ship was moved 15 m west toward the median ridge crest. The bit took weight at 4818 mbrf (Table 1). The coring rate was satisfactory, but nearly every time the bit was picked up off the bottom, the hole collapsed. At 4833.8 mbrf (15.8 mbsf), the bit was raised to 4 mbsf to recover the core barrel. A total of 0.3 m of basalt and diabase rubble was recovered. Although the hole was filled with mud, it collapsed. The bit struck bottom a couple of times during a down heave of the ship while the hole continued to collapse. The bit was pulled clear of the seafloor to protect the drill string from compressional damage.

Test spud-ins at Site 732 suggest that the median ridge is capped by at least 5 m of soft sediment overlying sand and gravel that contain boulders of considerable size and quantity. We do not know how thick this material is; it is too unstable for drilling. Hence, Site 732 was deemed unsuitable for guidebase deployment and was abandoned. The *JOIDES Resolution* departed for Site 733 at 0830 hr on 31 October 1987.

## SEDIMENTOLOGY

A 135-cm-thick section of sediment was recovered from Hole 732B (Section 118-732B-1D-1) overlying 15 cm of weathered basalt pebbles. These sediments, and about 10 cm$^3$ of sediment scraped from the bit in Hole 732F (Core 118-732F-2B), were the only sediments recovered at Site 732. Drilling disturbance was severe throughout, and no unambiguous sedimentary structures were observed. Two lithologies are present in the upper 70 cm: (1) a very dark grayish brown, well-sorted, medium- to coarse-grained volcanogenic sand (90%), and (2) a yellow brown muddy siliceous ooze (10%). The sand consists chiefly of rock fragments and subrounded grains of plagioclase and pyroxene, with about 10% broken foraminifers and siliceous debris. The ooze contains about 60% siliceous microfossils, 35% clay, and 5% broken foraminifers.

The interval between 70 and 95 cm in Section 118-732B-1D-1 contains gravel as well as the sand and ooze described above. The gravel consists of subrounded pieces of weathered basalt and serpentinite up to 2 cm in diameter. Between 95 and 135 cm, the core contains 60% to 70% yellow brown muddy siliceous ooze, 20%-30% black basalt gravel pieces, and 10% very dark grayish brown, coarse volcanic sand.

The volcanic sand and the muddy siliceous ooze are recognized as distinct lithologies, despite severe coring disturbance. These lithologies probably represent separate modes of sedimentation. The fine grain size and large biogenic fraction of the ooze indicate that it is pelagic in origin. The coarse-grained, well-sorted character of the sand and the rounded nature of the grains suggest deposition from density currents or reworking by bottom currents. Large slump scars on the walls of the fracture zone and associated fans in the axis were identified in detailed bathymetry (H. Dick, unpubl. data). Turbidity currents originating from large-scale mass movements may have distributed both sand and gravel along the floor of the fracture zone. Alternatively, episodes of strong northward bottom-current flow (Warren, 1978) may have reworked volcanic debris on the fracture zone floor to form the well-sorted sand beds.

## BIOSTRATIGRAPHY

At Site 732, sediments were recovered from Section 118-732B-1D-1 and from Core 118-732F-2B, where they were scraped off the drill bit. The sediments from Hole 732F may have come from any depth over the drilled interval of 0 to 15.8 mbsf, but probably are from near the surface. The biogenic content of the sediments was analyzed in smear slides. All samples contain abundant diatom fragments and sponge spicules. Some foraminifers, calcareous nannofossils, radiolarians, and silicoflagellates also are present. Preservation of all fossil groups is poor.

Sediments are dated as mid-Pleistocene, probably between about 0.268–0.458 Ma, based on calcareous nannofossils. The occurrence of Oligocene to Pliocene age indicators, together with distinctly Pleistocene species (the latter dominate), suggests significant reworking and/or slumping at this site.

### Calcareous Nannofossils

The sediments from Hole 732F and eight smear slides from Hole 732B were examined for their content of calcareous nannofossils (Samples 118-732B-1D-1, 12, 40, 66, 85, 102, 116, 125, and 140 cm). Two samples (118-732B-1D-1, 64 and 139 cm) were also analyzed using scanning electron microscopy (SEM). Taxonomy follows Perch-Nielsen (1985), and biostratigraphic zonation is after Martini (1971).

All samples contain the same assemblage: mainly small ($<4$ μm) placoliths and *Calcidiscus leptoporus* and some *Coccolithus pelagicus* and ceratoliths. A few specimens of reworked Oligocene-Pliocene species also were observed (*Cyclicargolithus abisectus, Dictycoccites* sp., *Discoaster brouweri, D. variabilis, D.*

*quinqueramus*, *Helicosphaera sellii*, *Pseudoemiliania lacunosa*, *Reticulofenestra umbilicus*, *R. pseudoumbilicus*). Preservation is poor, and the assemblage is enriched in solution-resistant forms.

*Gephyrocapsa oceanica* and other *Gephyrocapsa* species are well established, but *Emiliania huxleyi* was not observed. Only two specimens of *P. lacunosa* and few *H. sellii* were observed after many hours of analysis; these probably represent reworked specimens. Thus, the sediments are tentatively assigned to Zone NN20. The last occurrence of *P. lacunosa* is estimated to have occurred at 0.458 Ma, and the first occurrence of *E. huxleyi* is estimated at about 0.268 Ma by Thierstein et al. (1977), giving the ages of the lower and upper boundaries of this zone.

## LITHOSTRATIGRAPHY

The only materials recovered from the six holes drilled at Site 732 are unconsolidated lithic granules, pebbles, and cobbles interlayered with indurated sandstone, poorly consolidated sand, and tan, muddy siliceous ooze. Drilling operations suggested that in each hole a few (2–8) meters of soft material overlies a harder unit. The upper soft sediment is probably represented by the muddy siliceous ooze, and the lower unit by igneous and metamorphic breccia or conglomerate with interlayered sand and sandstone.

Siliceous ooze was recovered only in Core 118-732B-1D and from the bit in Hole 732F (Core 118-732F-2B) after the pipe was tripped. The sediment contains Quaternary and reworked Oligocene-Pliocene fauna (see "Biostratigraphy" section, this chapter). In the other cores this material probably washed out of the core barrel during drilling or in transit to the surface.

The coarse grains and clasts in the harder, lower unit range from less than 1 to 8 cm in maximum dimension and include igneous, metamorphic, and sedimentary rocks. All are subangular and have slightly rounded edges and buff to gray, weathered surfaces. All clearly are clasts in a poorly lithified deposit, not fragments produced as a consequence of drilling. Some of the igneous clasts have thin patches of indurated sand on their surfaces, indicating that they derive from a poorly sorted deposit partially cemented by iron-oxyhydroxides.

The clasts of sedimentary rock are small fragments of well-sorted, medium- to coarse-grained, reddish sandstone. One piece is graded from medium to fine sand. Grains are angular and include diverse lithic and mineral fragments. An unlithified sand interval in Core 118-732B-1D includes grains of similar size and composition.

Igneous and metamorphic clasts and very coarse grains in the breccia include plagioclase phyric basalt, aphyric basalt, metabasalt, greenstone, pyroxene gabbro, metagabbro, serpentinite, serpentinized peridotite mylonite, amphibolite gneiss, ferrogabbro, and diabase. Basalt and diabase are volumetrically the most common of the recovered clasts.

The upper part of the median ridge in the Atlantis II Fracture Zone appears to be a poorly sorted breccia or conglomerate interlayered with moderately to well-sorted immature sand and sandstone, overlain by a thin cover of pelagic sediment. The clast sizes and lithologies are similar to gravels recovered from the floor of the fracture zone east of Site 732 (H.J.B. Dick, pers. comm., 1987). These deposits are probably debris flows and turbidity deposits shed from the steep walls of the fracture zone. The cored breccia may be such basinal deposits that have been uplifted by faulting or by serpentinite intrusion along the median ridge. They could also be materials deposited from debris flows having sufficient velocity to have overwashed the median ridge.

## PETROGRAPHY

### Introduction

Holes 732A through 732F were spudded into an unknown thickness of clastic sediment and rubble. Approximately 3.5 m of rock and sediment was recovered from six holes, with a maximum penetration depth of 24 mbsf in Hole 732C and a maximum recovery of 23.8% in Hole 732B (Table 1). Material recovered includes a range of fresh, altered, and/or deformed mafic and ultramafic rock types. Relative proportions of all rock types recovered are listed in Table 2. For clast sizes greater than 2 cm, basalt, diabase and gabbro (in decreasing order of abundance) predominate (Table 2); ultramafic materials constitute less than 3% of the total. For clast sizes between 1 and 2 cm, however, basalt, gabbro and serpentine occur in roughly equal proportions (Table 2). This section reviews the petrography of the primary mineral assemblages; alteration and deformation of these samples are discussed in a subsequent section on alteration.

### Petrography of Rubble Clasts

*Basalt*

Basaltic rocks range from aphyric to sparsely plagioclase or olivine phyric. Aphyric and plagioclase phyric samples predominate and occur in roughly equal proportions. Olivine phenocrysts, approximately 0.5 mm across, occur only in Sample 118-732F-1R-1, 0–4 cm, although olivine microphenocrysts (< 1 mm in size) were identified in Samples 118-732C-2D-1, 14–17 cm and 118-732C-2D-1, 19–21 cm. The microphenocrysts in these samples are now totally replaced by clay minerals and calcite. Plagioclase phenocrysts range from 1 to 6 mm in size and generally make up less than 4% of the rock, although one meta-basalt fragment (Sample 118-732E-1R-1, 15–20 cm) contains approximately 25% plagioclase phenocrysts up to 3 mm in size. Plagioclase constitutes 45%–50%, clinopyroxene 5%–45%, and olivine, if present, less than 8% of the groundmass. All basalt clasts have quench crystallization textures consisting of plagioclase sheaf structures and, in some cases, lantern groundmass olivine (now totally replaced by chlorite or clay). Although groundmass textures indicate relatively rapid cooling for these basalts, no glass was recovered. Vesicles were observed in only two samples; in Sample 118-732C-2D-1, 14–17 cm, these were filled by smectite and in Sample 118-732D-1D-1, 0–5 cm, by chlorite.

Alteration consists predominantly of plagioclase replacement by chlorite, clay minerals, epidote, and/or albite. Olivine is replaced by calcite or chlorite and cryptocrystalline groundmass, by clay minerals or chlorite.

*Diabase*

Diabase clasts recovered from Holes 732A through 732F are predominantly fine-grained, dark to medium gray rocks. They consist of approximately 50% plagioclase, 20%–30% clinopyroxene, and 5%–10% iron and titanium oxides. Olivine, which probably constituted 10%–15% of the primary assemblage, has been totally replaced by clay minerals and iron and titanium oxides. Textures range from equigranular to subophitic.

One unusual sample, 118-732D-1D-1, 20–30 cm, has 1%–2% plagioclase phenocrysts/xenocrysts up to 1 cm in size; smaller (2 mm), less abundant iron and titanium oxide xenocrysts also occur. This sample is by a fine-grained basaltic dikelet, approximately 1 cm wide (Fig. 7). Contacts between the dikelet and host diabase are sharp, but chilled margins are not apparent. The basaltic dikelet contains plagioclase xenocrysts, probably incorpo-

**Table 2. Lithologic summary for all clast types.**

| Rock type | | Number of clasts | Percentage |
|---|---|---|---|
| Clasts < 1 cm | | | |
| Basalt | | 38 | 33.9 |
| Gabbro | | 23 | 20.5 |
| Serpentine | | 20 | 17.8 |
| Diabase | | 17 | 15.2 |
| Greenstone | | 5 | 4.5 |
| Lithic sandstone | | 3 | 2.7 |
| Gabbroic gneiss | | 2 | 1.8 |
| Greenschist facies microbreccia | | 2 | 1.8 |
| Serpentinized peridotite/mylonite | | 1 | 0.9 |
| Serpentinized harzburgite | | 1 | 0.9 |
| Clasts > 2 cm | | | |
| Basalt | | 14 | 45.2 |
| aphyric | (19.4%) | | |
| plagioclase phyric | (19.4%) | | |
| vesicular, plagioclase phyric | (3.2%) | | |
| olivine phyric | (3.2%) | | |
| Diabase | | 8 | 25.8 |
| Gabbro | | 3 | 9.7 |
| Lithic sandstone | | 3 | 9.7 |
| Gabbroic gneiss | | 1 | 3.2 |
| Serpentinized peridotite/mylonite | | 1 | 3.2 |
| Serpentinized harzburgite | | 1 | 3.2 |
| Clasts 1–2 cm | | | |
| Weathered basalt | | 24 | 29.6 |
| Gabbro | | 20 | 24.7 |
| Serpentine | | 20 | 24.7 |
| Diabase | | 9 | 11.1 |
| Greenstone | | 5 | 6.2 |
| Greenstone facies microbreccia | | 2 | 2.5 |
| Gabbroic gneiss | | 1 | 1.2 |

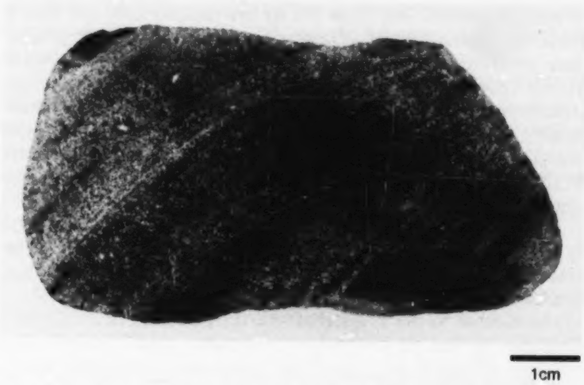

Figure 7. Diabase Sample 118-732D-1D-1, 20–30 cm, with crosscutting basaltic dikelet. Basaltic dikelet extends from upper left to lower right of sample and is approximately 1 cm wide.

rated from the diabase wall rock. The dikelet exhibits significantly more oxidative alteration than the adjacent diabase.

Alteration in most diabase clasts consists of replacement of olivine and/or interstitial glass by clay minerals and minor replacement of plagioclase by clay minerals or chlorite. One diabase contains a greenschist-grade secondary mineral assemblage (see "Alteration, Metamorphism and Deformation" section, this chapter).

### *Gabbro*

Gabbro clasts range from moderately (10%–40%) to very highly (80%–95%) altered and deformed and are probably best described as metagabbros. Structurally, they range from massive to foliated. Texturally, they range from coarse- to very coarse-grained, with plagioclase and clinopyroxene crystals up to 1 cm in size. Most samples recovered are one-pyroxene gabbros consisting of 45%–80% plagioclase, 20%–40% clinopyroxene, and less than 5% iron and titanium oxides.

Neither orthopyroxene nor olivine is believed to have been present in the primary mineral assemblages of most gabbro samples recovered, but this was difficult to assess because of the nearly complete replacement of primary minerals in most samples. However, petrographic evidence suggests that completely serpentinized porphyroclasts in Samples 118-732D-1D-1, 7–8 cm, and 118-732B-1D-2, 5–6 cm, have replaced orthopyroxene. These samples originally contained 30%–50% plagioclase, 30% clinopyroxene, 8%–10% orthopyroxene, 2%–20% iron and titanium oxides, and 10% hornblende. Sample 118-732D-1D-1, 7–8 cm, also contains traces of euhedral apatite up to 1 mm in length. The reddish-brown hornblende that surrounds cumulate ilmenite in this sample is apparently primary. In contrast to the one-pyroxene assemblages, this mineralogy suggests that these rocks are probably ferro-gabbros. Like the one-pyroxene gabbros, Sample 118-732D-1D-1, 7–8 cm, is very coarse-grained and massive. Sample 118-732B-1D-2, 5–6 cm, is a medium-grained, foliated rock, but was probably also coarse-grained originally as porphyroclasts of up to 5 mm were observed.

### *Ultramafic Rocks*

Ultramafic rocks recovered at Site 732 consist almost exclusively of serpentinite. In Sample 118-732A-1D-1, 0–4 cm, a serpentinite mylonite peridotite, almost all evidence of primary mineralogy has been lost because of extensive alteration and deformation. However, Samples 118-732B-1D-2, 8–9 cm, and 118-732D-1D-1, 12–18 cm, are far less deformed and contain bastite pseudomorphs after pyroxene (up to 5 mm in size) and relict holly-leaf chromium-spinel. Some bastite pseudomorphs in Sample 118-732B-1D-2, 8–9 cm, also contain primary clinopyroxene having orthopyroxene exsolution lamellae. These samples probably were originally coarse-grained harzburgites.

### *Lithic Sandstone*

Three fragments of lithic sandstone were recovered along with the various mafic and ultramafic samples from Hole 732C (118-732C-2D-1, 25–35 cm; 118-732C-2D-1, 35–39 cm; 118-732C-3D-1, 27–30 cm). Consistent with the predominant recovery of basalt among the larger clast sizes (>1 cm), the sandstones consist principally of basalt and diabase fragments (20%) and plagioclase (21%). Most basalt clasts have quench textures (i.e., plagioclase sheaf structures) similar to those described previously, as well as variolitic structures and palagonitized glass. A variety of secondary alteration minerals constitute the remainder of the rock (Table 3). The grains are cemented by a dark red opaque material, probably a ferro-manganese oxyhydroxide.

### Summary

A wide variety of intrusive and extrusive rocks was recovered from the sedimentary unit cored in Holes 732A through 732F. Clasts greater than 1 to 2 cm are predominantly mafic igneous rocks (basalt, diabase, and gabbro), accompanied by lesser amounts of altered or metamorphosed equivalents and ultramafic materials.

## ALTERATION, METAMORPHISM, AND DEFORMATION

### Introduction

As discussed in the "Petrography" section (this chapter), the rubble samples provide a random selection of rocks from the transform fault wall. The basalts show variable degrees of low-

**Table 3. Point-count summary of lithic sandstone from Sample 118-732C-2D-1, 35-39.**

| Clast type | Point count | Percentage |
|---|---|---|
| Basalt and diabase | 153 | 20.4 |
| Plagioclase | 160 | 21.3 |
| Chlorite | 42 | 5.6 |
| Colorless amphibole | 38 | 5.1 |
| Clay minerals | 24 | 3.2 |
| Clinopyroxene | 16 | 2.1 |
| Blue-green amphibole | 5 | 0.7 |
| Iron-titanium oxides | 4 | 0.5 |
| Epidote | 3 | 0.4 |
| Prehnite | 3 | 0.4 |
| Spinel | 2 | 0.3 |
| Olivine | 2 | 0.3 |
| Sphene | 1 | 0.1 |
| Cement | | |
| Iron-manganese oxide | 297 | 39.6 |
| Total | 750 | 100.0 |

temperature oxidative alteration, with clay minerals filling fractures and replacing phenocrysts or glassy mesostasis. In contrast, some of the basalts and all of the gabbroic samples show evidence of medium- to high-temperature metamorphism. In these rocks, the temperature of metamorphism appears related to the state of deformation: static metamorphism occurred at relatively low temperatures (stability of greenschist facies minerals), cataclastic deformation occurred at low to medium temperatures (stability of greenschist facies to low-amphibolite facies minerals), and plastic deformation occurred at still higher temperatures. Only three samples of peridotite were recovered, a mylonite and two coarse-grained harzburgites, all of which were heavily serpentinized.

## Plastic Deformation of Gabbroic Rocks at High Temperature

One gabbro sample (118-732B-1D-2, 5-6 cm) shows a recrystallized and foliated texture (Fig. 8) with plagioclase neoblasts (mean size = 0.15 mm) and clinopyroxene grains that are 0.2 to 0.6 mm in size, surrounded by inclusion-free clinopyroxene neoblasts (less than 0.2 mm in size) and by blebs of brown hornblende. This texture was attributed to deformation-induced recrystallization of the gabbroic minerals at high temperatures. Evidence of such high-temperature recrystallization and deformation was documented for one of the DSDP Leg 37 gabbros (Helmstaedt, 1977) and for the Romanche, Vema, and Garrett transform zones (Hebert et al., 1983; C. Mevel, unpubl. data; Cannat, unpubl. data). Such high temperatures of metamorphism require proximity to a magma chamber and thus may be characteristic of the early cooling history of plutonic rocks near the ridge axis.

The sample also shows evidence of about 20% static alteration at lower temperatures: the cores of the clinopyroxene crystals are altered to a cloudy mesh of magnetite, serpentine, and clay minerals (Fig. 9). The primary ilmenite is rimmed by or intergrown with chlorite; small ilmenite inclusions in the plagioclase are replaced by sphene and fine-grained secondary magnetite; and euhedral pyrite crystals occur as inclusions in the plagioclase. The sample also displays relatively large, blocky, serpentinized porphyroclasts (1 mm in size) that may be igneous orthopyroxene, based on the presence of clinopyroxene exsolution lamellae (Fig. 10). If this interpretation is correct, the original gabbro was geochemically evolved with cumulus orthopyroxene.

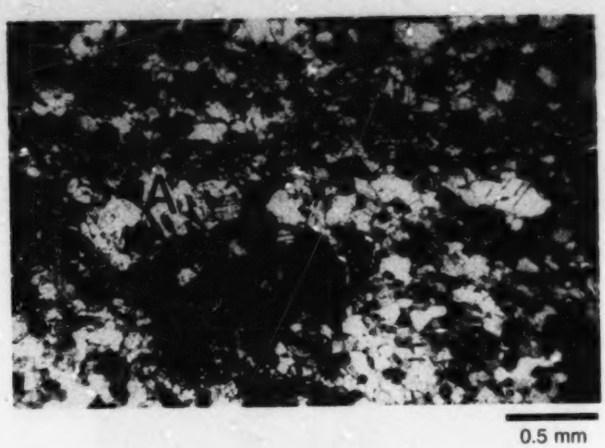

Figure 8. Foliated gabbro gneiss (Sample 118-732B-1D-2, 5-6 cm): recrystallized plagioclase and clinopyroxene (A). Crossed nicols.

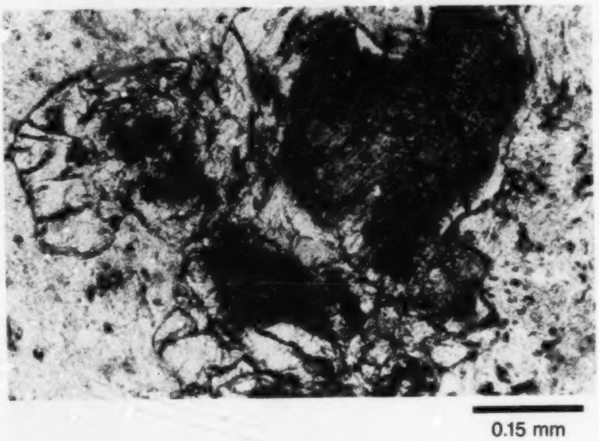

Figure 9. Foliated gabbro gneiss (Sample 118-732B-1D-2, 5-6 cm). Clinopyroxene crystals with cores altered to a mesh of magnetite, serpentine, and clays, caused by post-deformation static alteration. Plane light.

## Medium-Temperature Metamorphism and Cataclastic Deformation

Three gabbro samples (118-732C-3D-1, 5-10 cm, 118-732C-3D-1, 15-18 cm, Piece 4; and 118-732C-3D-1, 20-23 cm) are cut by fractures, which, from one sample to the next, may be randomly oriented or roughly parallel. The clinopyroxene is partly to completely replaced by brown to green hornblende (Fig. 11). Near the fractures, these hornblende crystals are kinked and partly recrystallized, either into smaller grains of the same hornblende or into a more actinolitic amphibole (Fig. 12). This suggests that the cataclastic deformation occurred over a range of decreasing temperatures. The response of plagioclase to deformation is also characteristic of a decrease in temperature: it may be locally recrystallized (Fig. 11), but more commonly it is crushed, heavily veined, and replaced by a fine aggregate of actinolite, epidote, and chlorite.

The metamorphic textures in these rocks are quite complex. The original ilmenite is heavily altered, with relict grains containing anatase or rutile inclusions and surrounded by jackets of coarse sphene (Fig. 13). In Sample 118-732C-3D-1, 15-18 cm, a characteristic (coronitic) replacement pattern preserves the rela-

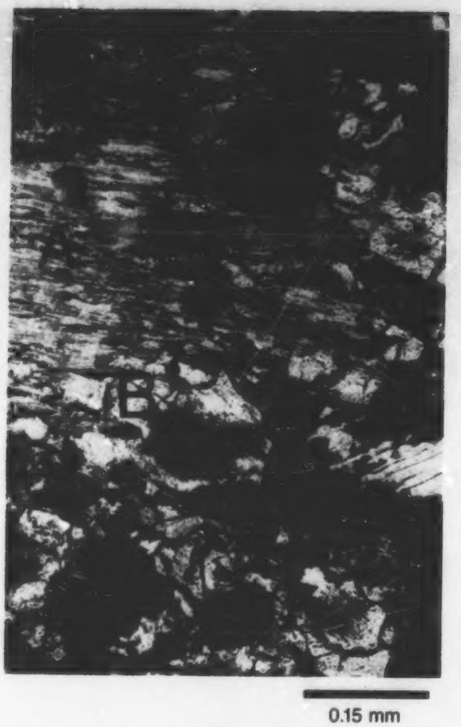

Figure 10. Foliated gabbro gneiss (Sample 118-732B-1D-2, 5–6 cm). Serpentinized porphyroclast (A) of what may be igneous orthopyroxene, based on the presence of clinopyroxene exsolution lamellae (B). Crossed nicols.

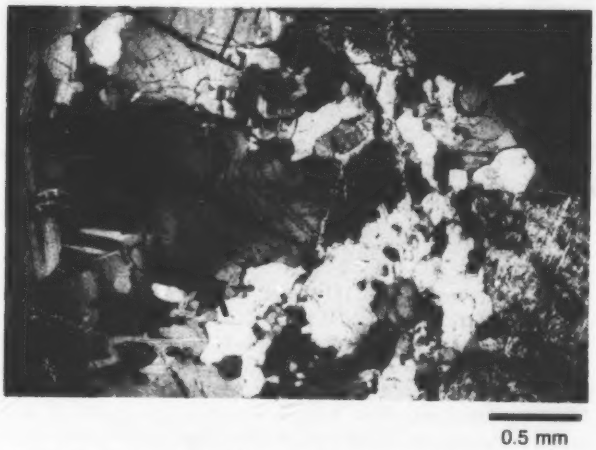

Figure 11. Recrystallized plagioclase (A), clinopyroxene partly altered to brown hornblende and actinolite (B) and a late chlorite vein (C). Gabbro Sample 118-732C-3D-1, 15–18 cm. Crossed nicols.

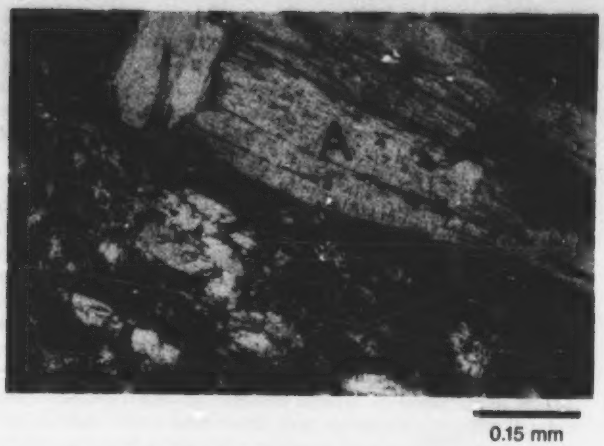

Figure 12. Green hornblende porphyroclast (A) recrystallized into margins of actinolitic porphyroblasts (B) in a zone of cataclastic deformation. Gabbro Sample 118-732C-3D-1, 20–23 cm. Crossed nicols.

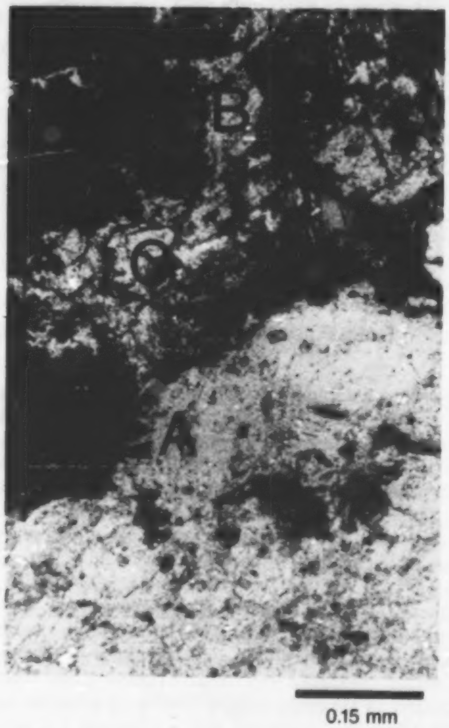

Figure 13. Primary igneous ilmenite (A) replaced by a jacket of coarse sphene (B) with one grain of included epidote (C). Gabbro Sample 118-732C-3D-1, 5–10 cm. Plane light.

tionship of the primary minerals. As illustrated in Figure 14, plagioclase is replaced by chlorite, the boundary between plagioclase and the mafic phase is replaced by a colorless magnesian amphibole, and the core of the mafic phase is replaced by unidentified mineral dissected by rods of magnetite. The pseudomorphed mafic phase may have been pyroxene because the magnetite rods in some of the grains appear to mimic cleavage planes. Veins of green hornblende, epidote (clinozoisite), and chlorite crosscut the foliation or the fractures. The magnetites are martitized, and most of the magnetite has been oxidized to hematite. A red vein sampled for XRD identification from Sam-

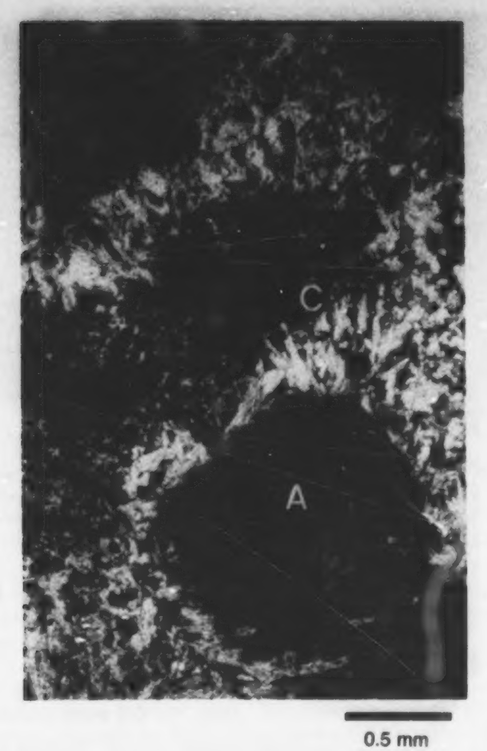

Figure 14. Metamorphic reaction rim in gabbro Sample 118-732C-3D-1, 15–18 cm. The surrounding plagioclase is replaced by chlorite (A). The boundary between plagioclase and the altered mafic phase (see text) is replaced by magnesian amphibole (B). The core of the mafic phase is replaced by unidentified mineral, dissected by rods of magnetite (C). Crossed nicols.

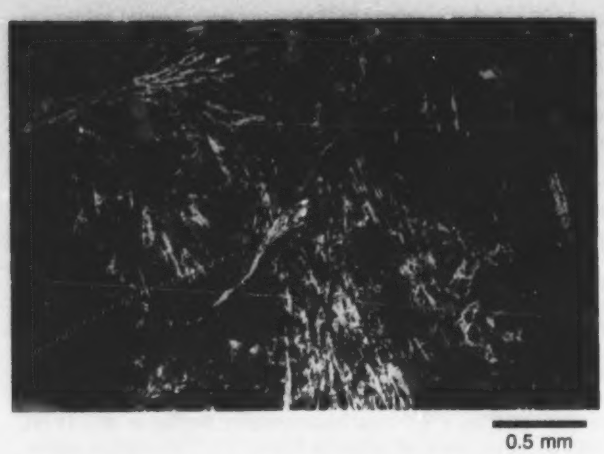

Figure 15. Greenschist facies altered basalt, Sample 118-732D-1D-1, 0–6 cm. An epidote-chlorite vein crosscuts the sample. Epidote and chlorite also fill the adjacent vesicle. Crossed nicols.

ple 118-732C-3D-1, 5–10 cm, proved to be a mixture of hematite and smectite.

### Static Hydrothermal Alteration at Moderate Temperatures

Four pebbles of holocrystalline basalt (118-732B-1D-2, 6–7 cm; 118-732D-1D-1, 0–5 cm; 118-732D-1D-1, 21–25 cm; and 118-732E-1R-1, 17–20 cm) contain secondary chlorite, epidote, and actinolite. Chlorite replaces much of the plagioclase in these rocks and fills veins and vesicles. Epidote also fills veins and vesicles (Fig. 15) and replaces the cores of some of the plagioclase phenocrysts in Sample 118-732D-1D-1, 0–6 cm. Very thin veins of quartz (1–2 mm) that crosscut the basalt matrix have an *en-echelon* pattern resulting from shearing that is contemporaneous with quartz deposition. Much of the clinopyroxene in Sample 118-732B-1D-2, 6–7 cm, is replaced by epidote, whereas the plagioclase is replaced by acicular actinolite and lesser quantities of pale chlorite.

Of the plutonic rocks, one ferrogabbro (Sample 118-732D-1D-1, 7–8 cm) contains evidence of limited static metamorphism at moderate temperatures. In this sample, acicular actinolite replaces brown igneous hornblende and lesser quantities of plagioclase. The actinolite is itself partly replaced by brown smectite. In addition, serpentine-magnetite pseudomorphs replace either orthopyroxene or olivine. Large cumulus ilmenite phenocrysts have exsolved into two phases at temperatures equal to or greater than 600°C: a titanium-rich hematite and an iron-rich ilmenite. The phenocrysts also contain small, dark gray rods of what may possibly be pleonaste. An included relict crystal of serpentinized olivine (?) contains both chalcopyrite and pyrite.

Finally, Sample 118-732B-1D-2, 9–10 cm, is a chip from a prehnite vein through a clinopyroxene- and orthopyroxene-bearing rock, probably a coarse-grained gabbro. The prehnite makes up about 90% of the sample and occurs as coarse, radial bundles (up to 3 mm wide) of bladed crystals. All the plagioclase apparently is replaced by prehnite, and the clinopyroxene is replaced by fine-grained actinolite and serpentine.

### Low-Temperature Alteration

None of the samples contain any evidence of long exposure to seawater at low temperatures (i.e., seafloor weathering) since becoming a rubble fragment. There are no red oxidation rims on the pebbles, and clay minerals are not concentrated along the rounded margins of the samples. Instead, low-temperature mineral assemblages preferentially replace primary phases (e.g., glass replaced by green smectite). These observations suggest that the alteration and metamorphism occurred before the inclusion of the pebbles in the rubble. Most extrusive rocks contain clay minerals, some of which are stained with iron oxide. These clay minerals range from about 2% to 30% and replace both phenocrysts and groundmass and fill vesicles and fractures. Most are microcrystalline and probably smectite. Coarser aggregates of clay minerals appear to be green saponite or brown nontronite. No zonation of clay minerals was observed. Only trace amounts of other low-temperature minerals (zeolite and carbonate) occur in the vesicles. In one sample (118-732C-2D-1, 19–21 cm), olivine is replaced by calcite and some plagioclase may be replaced by potassium feldspar. This sample has a high $K_2O$ content (see "Geochemistry" section, this chapter). Similar secondary mineral assemblages, observed in DSDP Holes 417A and 504B, were ascribed to low-temperature hydrothermal alteration under oxidative conditions (Scheidegger and Stakes, 1979; Pertsev and Boronikkin, 1983).

### Ultramafic Rocks

Two very different ultramafic rocks were recovered at Site 732: a highly serpentinized, coarse-grained harzburgite (Samples 118-732B-1D-2, 8–9 cm, and 118-732D-1D-1, 8–9 cm) and a serpentinized peridotite mylonite (Sample 118-732A-1D-1, 0–4 cm). The coarse-grained harzburgite was plastically deformed under mantle conditions and shows a rough foliation marked by elongated orthopyroxene. Its subsequent serpentinization was static: a coarse mesh of serpentinite and magnetite replaces the olivine, and the pyroxenes are pseudomorphed by bastite. The spinel rims are replaced by magnetite. Chrysotile or lizardite veins having fibers perpendicular to the walls crosscut the samples.

The serpentinized peridotite mylonite is a strongly foliated rock composed mostly of serpentinite and magnetite. Magnetite is abundant (about 5%), varies greatly in size, and is distributed parallel to the foliation. A fine layering, parallel to the foliation, is defined by 1-mm-thick aggregates of actinolite or smectite mixed with the magnetite and fine-textured hematite (an oxidative alteration of the magnetite) in the serpentinite groundmass (Fig. 16). Rounded augen, composed of serpentinite and iron chromite enclosed in halos of green chlorite, appear to have been rotated in the foliation plane (Fig. 17), and the serpentinite foliation itself is locally deformed by microshear planes oblique to the foliation ("C"-type microshears; Berthe et al., 1979), with a dextral sense of offset in Figure 17. This type of microstructure is typical of a noncoaxial deformation regime.

The rounded shape of the augen and the very fine-grained texture of the serpentinite suggest that the rock was already a mylonite before serpentinization. The fine-grained serpentine replaced fine-grained mylonitized olivine, and the augen, now filled with serpentine and magnetite, may have been olivine or orthopyroxene porphyroclasts. The actinolite or smectite aggregates may be replacements of the original stretched orthopyroxenes or clinopyroxenes. If this hypothesis is correct, it implies that the deformation began at high temperatures, produced a peridotite mylonite, and continued at lower temperatures during the serpentinization process.

## GEOCHEMISTRY

Five samples were analyzed for major and trace elements using the shipboard XRF system. The method is outlined in the "Introduction and Explanatory Notes" (this volume).

The analyzed samples include two aphyric basalts, one plagioclase-phyric basalt, one diabase, and one pyroxene gabbro. Results are summarized in Table 4. The weight loss on ignition (LOI) was determined gravimetrically; it reflects both loss of volatiles and uptake of oxygen from oxidation of ferrous iron during ignition. The relatively high LOI values for most samples attest to the presence of abundant secondary hydroxyl-bearing minerals.

The basalts are moderately fractionated, have magnesium numbers between 61 and 67, and contain less than 100 ppm of nickel. Nevertheless, these basalts rank among the least fractionated ones recovered from the Atlantis II Fracture Zone, as illustrated in Figure 18. The relatively high $TiO_2$, MnO, $Na_2O$, and $P_2O_5$ contents are in keeping with data for basalts dredged from the Southwest Indian Ridge (le Roex et al., 1983; Snow et al., in press). While the high potassium content of Sample 118-732C-2D-1, 21-23 cm, presumably results from low-temperature seawater alteration, the potassium content of the other samples is within the range of fresh Atlantis II Fracture Zone glasses analyzed by Snow et al. However, rubidium contents of the Site 732 samples are 1 to 3 ppm higher than for the Atlantis II Fracture Zone glasses, which implies that most of the samples have taken up rubidium during alteration. Diabase Sample 118-732D-1D-1, 20-25 cm, is more fractionated than the basalt (e.g., lower magnesium number, nickel, and chromium) and has the composition of an iron-titanium basalt.

The four basalts (including the diabase) from Site 732 are characterized by high zirconium/niobium (>32) and yttrium/niobium (≥8.6) ratios and clearly correspond chemically to the group of "depleted"-N-type, ocean-floor basalts that le Roex et al. (1983) found to be an ubiquitous lava type that erupted along the western end of the Southwest Indian Ridge between the Bouvet triple junction and 11°E. For example, this is illustrated by the yttrium vs. zirconium and niobium vs. zirconium diagrams shown in Figure 19 and confirmed by shore-based instrumental neutron-activation analyses of Samples 118-732C-2D-1, 12-15 cm, and 118-732D-1D-1, 20-25 cm, performed immediately after the cruise at the University of Leuven.

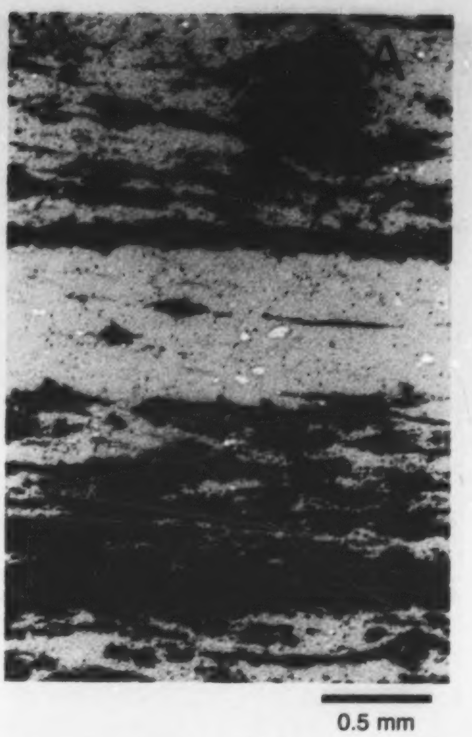

Figure 16. Serpentinized peridotite mylonite, Sample 118-732A-1D-1, 0-4 cm. The dark layers, parallel to the foliation, are composed of actinolite or smectite mixed with magnetite and hematitic alteration of the magnetite. The light layers are predominantly fine-grained serpentine. Also illustrated is a rounded augen of serpentinite and chromite (A). Plane light.

The consistently high abundances of incompatible elements such as titanium, zirconium, niobium, and yttrium in basalts derived from depleted sources are a strong indication that Atlantis II Fracture Zone basalts were formed by small degrees of partial melting, as predicted by recent tectono-magmatic models for fracture zones (e.g., Fox and Gallo, 1984).

The chemistry of pyroxene gabbro Sample 118-732C-3D-1, 20-23 cm, does not correspond to mid-ocean ridge basalt liquid compositions. The high chromium and strontium contents, coupled with low concentrations of titanium, vanadium, yttrium, zirconium, and niobium, indicate that this rock is a clinopyroxene plus plagioclase cumulate.

## SUMMARY AND CONCLUSIONS

Site 732 is located on the median tectonic ridge of the Atlantis II Fracture Zone between 32°32.81'S, 57°03.289'E and 32°32.85'S, 57°02.7'E. This site was selected as the primary target for a deep reentry hole in upper mantle peridotite. Serpentinized peridotite was dredged from the median ridge during the site survey and was believed to crop out on the seafloor. The operational plan called for a television/sonar survey, a test spud-in at one or more favorable locations, setting of the hard-

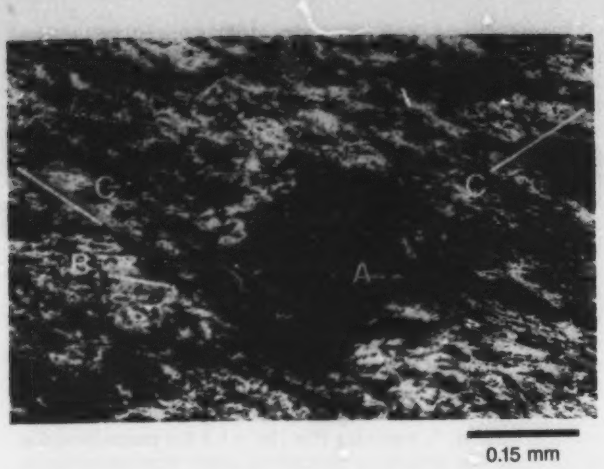

Figure 17. Rotated serpentine and iron chromite augen having green chlorite pressure-shadows (A) that indicate dextral shear. Note that the serpentinite foliation (B) is deformed by oblique microshear planes (C) having a dextral sense of offset. Crossed nicols.

rock guidebase, and drilling a 500+-m hole into basement. An extensive program of logging and downhole measurements was planned after completion of drilling.

Upon arrival at the site, an E-shaped television/sonar survey was conducted along the crest of the ridge, with three transects extending down the west flank. The surveys revealed blocky and bouldery outcrops on steep slopes on the flanks of the ridge and a rubbly, sedimented surface on the top of the ridge. Two sites on the crest of the ridge were selected for test spud-in in areas topographically suitable for guidebase deployment.

Six holes were drilled at Site 732, three each in the two different locations on the ridge crest. The deepest hole reached 24 mbsf. A total of 3.51 m of core material was obtained for an average recovery of 5.1%. These materials consist entirely of lithic granules, pebbles and cobbles, indurated sandstone, poorly consolidated sand, and muddy siliceous ooze. Drilling indicated that each hole penetrated a few (2–8) meters of soft sediment overlying a harder unit. Thus, it is likely that two lithologic units are present on the ridge crest: an upper layer of soft, muddy, siliceous ooze and a lower layer of gravel or conglomerate composed of igneous and metamorphic rock fragments containing interlayered sand and sandstone.

Calcareous nannofossils in the muddy siliceous ooze were tentatively assigned to Zone NN20 and dated as mid-Pleistocene, probably between 0.27 and 0.46 Ma (minimum 0.08, maximum 1.45 Ma). Sparse Oligocene to Pliocene species in the sediments suggest significant reworking and/or slumping at this site.

The lithic sandstone recovered at Site 732 consists primarily of basalt and diabase fragments and plagioclase, with lesser amounts of chlorite, amphibole, and clay minerals cemented by iron and manganese oxides.

The recovered clasts of igneous and metamorphic rock include basalt, diabase, gabbro, and minor serpentinized ultramafic rocks. Among the basalt clasts, aphyric and plagioclase-phyric varieties predominate. Sparse olivine phenocrysts or microphenocrysts are also present in three specimens. All of the basalts have quench textures, but no glass was recovered. Small, sparse vesicles, filled with chlorite or smectite, are present in two samples. Alteration is variable, while plagioclase is partly replaced by clay minerals, calcite, and chlorite; olivine is replaced by clay minerals, calcite, and chlorite; and interstitial

Table 4. Chemical data for Site 732 samples.

| Hole | 732C | 723C | 732C | 732D | 732F |
|---|---|---|---|---|---|
| Section | 2D-1 | 2D-1 | 3D-1 | 1D-1 | 1R-1 |
| Interval (cm) | 12–15 | 21–23 | 20–23 | 20–25 | 31–34 |
| Piece no. | 3 | 4 | 5 | 4 | 7 |
| Rock type | PB | AB | GA | DI | AB |
| (in wt%) | | | | | |
| $SiO_2$ | 49.88 | 51.62 | 50.10 | 49.84 | 50.16 |
| $TiO_2$ | 1.87 | 1.75 | 0.47 | 2.10 | 1.50 |
| $Al_2O_3$ | 17.77 | 17.04 | 14.52 | 14.79 | 15.91 |
| $Fe_2O_3$ | 9.17 | 8.15 | 10.15 | 12.14 | 9.96 |
| MnO | 0.15 | 0.25 | 0.16 | 0.19 | 0.16 |
| MgO | 6.39 | 6.07 | 9.91 | 7.16 | 8.36 |
| CaO | 11.39 | 10.91 | 12.86 | 10.23 | 11.14 |
| $Na_2O$ | 2.98 | 3.41 | 1.56 | 3.26 | 2.60 |
| $K_2O$ | 0.17 | 0.60 | 0.25 | 0.11 | 0.07 |
| $P_2O_5$ | 0.22 | 0.20 | 0.02 | 0.18 | 0.15 |
| LOI | 2.62 | 1.39 | 1.97 | 1.80 | 0.15 |
| (in ppm) | | | | | |
| V | 274 | 265 | 191 | 286 | 246 |
| Cr | 238 | 352 | 833 | 159 | 314 |
| Ni | 84 | 98 | 106 | 59 | 86 |
| Cu | 43 | 73 | 14 | 67 | 63 |
| Zn | 123 | 97 | 53 | 83 | 76 |
| Rb | 4 | 5 | 3 | 5 | 1 |
| Sr | 162 | 182 | 234 | 151 | 188 |
| Y | 43 | 41 | 22 | 38 | 31 |
| Zr | 156 | 148 | 61 | 142 | 119 |
| Nb | 4.3 | 4.3 | 2.4 | 4.4 | 3.4 |
| Ratios | | | | | |
| Mg no. (× 100) | 61.9 | 63.4 | 69.5 | 57.9 | 66.2 |
| Ca no. (× 100) | 67.9 | 63.9 | 82.0 | 63.5 | 70.3 |
| K/Rb | 350 | 1000 | 700 | 180 | 600 |
| K/Sr | 8.6 | 27.5 | 9.0 | 6.0 | 3.2 |
| Zr/Nb | 36.3 | 34.4 | 25.4 | 32.3 | 35.0 |
| Zr/Y | 3.62 | 3.61 | 1.41 | 3.74 | 3.84 |
| Y/Nb | 10 | 9.5 | 9.2 | 8.6 | 9.1 |

Major element data on anhydrous basis and normalized to sum = 100%. PB = plagioclase phyric basalt; AB = aphyric basalt; GA = gabbro; DI = diabase. LOI = loss on ignition. MG no. = $(Mg/Mg + 0.85\ Fe_{tot})_{molar}$; Ca no. = $(Ca/Ca + Na)_{molar}$.

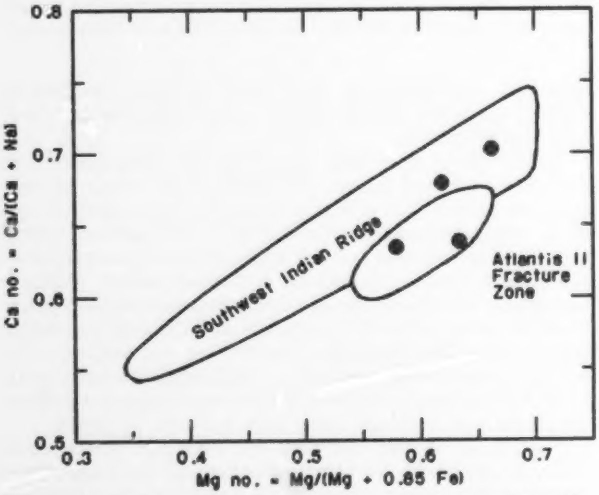

Figure 18. Calcium-number vs. magnesium-number for Site 732 basalts. Southwest Indian Ridge dredged basalt data from le Roex et al. (1983); Atlantis II Fracture Zone glass data from Snow et al. (in press).

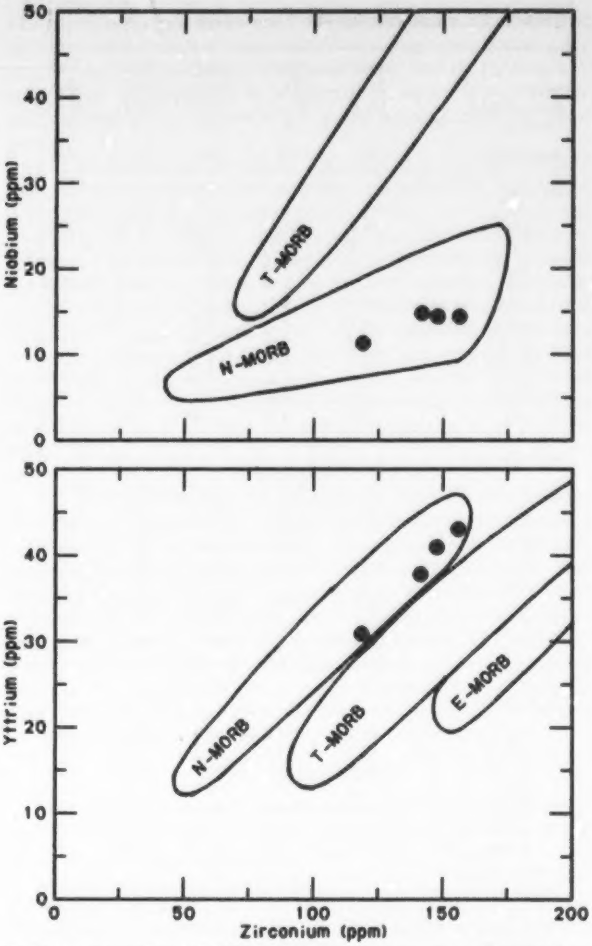

Figure 19. Zirconium, niobium, and yttrium contents of Site 732 basalts. Fields for Southwest Indian Ridge-dredged basalts from le Roex et al. (1983). The Site 732 basalts fall within the field of depleted normal Mid-Ocean Ridge (N-MORB) basalts. T-MORB = Transitional Mid-Ocean Ridge basalts. E-MORB = Enriched Mid-Ocean Ridge basalts.

material is replaced by clay minerals and chlorite. The diabase samples are mineralogically similar to the basalts but are somewhat coarser-grained.

Gabbro clasts range from moderately to highly altered and deformed, and from massive to foliated. Most consist of one-pyroxene gabbro, but a ferrogabbro may have originally had both orthopyroxene and clinopyroxene. One gabbro sample shows plastic deformation and high-temperature recrystallization with neoblasts of plagioclase and clinopyroxene. Medium-temperature alteration of other samples is manifested by replacement of the pyroxene by amphibole and by some cataclastic deformation. The ferrogabbro sample was subjected to static metamorphism at high to moderate temperatures, as manifested by actinolite replacing brown amphibole and serpentine-magnetite assemblages replacing either orthopyroxene or olivine.

Three pieces of ultramafic rock were recovered: two pieces of highly serpentinized, foliated harzburgite and one piece of serpentinized peridotite mylonite. In all cases, the serpentinization was probably static.

From the television/sonar survey, drilling operations, and recovered core material, the median tectonic ridge appears to be underlain by massive rock (peridotite?) and to be capped by a layer of poorly sorted breccia with interlayered sandstone. This sequence is overlain by a thin (2–8 m) layer of muddy siliceous ooze. We do not know exactly how thick the breccia layer is, but it is more than 20 m at Site 732. Clasts from the breccias are similar in size and composition to those recovered during the site survey from gravels on the floor of the transform farther south. These deposits were probably laid down by debris flows and turbidity currents originating on the steep walls of the transform. The appearance of these basinal sediments on top of the median ridge suggests uplift of that feature either by faulting or by serpentinite diapirism. Based on the age of the sediments, the uplift probably occurred after mid-Pleistocene time, which is probably only a small fraction of the transform age (~ 20 Ma). The inferred rates of uplift of the ridge are in the range of 0.3 to 0.5 cm/yr$^{-1}$, assuming that the ~ 1.5 km excess elevation of the ridge was created by continuous uplift from inception to the present day.

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**Ms 118A-104**

# 4. SITE 733[1]

## Shipboard Scientific Party[2]

### HOLE 733A

**Date occupied:** 31 October 1987

**Date departed:** 2 November 1987

**Time on hole:** 34 hr

**Position:** 33°05.30′S, 56°58.68′E

**Bottom felt (rig floor, m; drill pipe measurement):** 4494.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4482.9

**Total depth (rig floor, m):** 4510.6

**Penetration (m):** 16.6

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 16.6

**Total core recovered (m):** 0.0

**Core recovery (%):** 0

### HOLE 733B

**Date occupied:** 2 November 1987

**Date departed:** 3 November 1987

**Time on hole:** 17 hr

**Position:** 33°05.30′S, 58°58.68′E

**Bottom felt (rig floor, m; drill pipe measurement):** 4498.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4486.9

**Total depth (rig floor, m):** 4502.3

**Penetration (m):** 4.30

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 4.30

**Total core recovered (m):** 0.09

**Core recovery (%):** 2.1

**Hard rock:**
  Depth (mbsf): Not known
  Nature: metagabbro and amphibolite rubble

### HOLE 733C

**Date occupied:** 3 November 1987

**Date departed:** 4 November 1987

**Time on hole:** 7 hr 15 min

**Position:** 33°05.30′S, 56°58.68′E

**Bottom felt (rig floor, m; drill pipe measurement):** 4498.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 4486.9

**Total depth (rig floor, m):** 4503.7

**Penetration (m):** 5.7

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 5.7

**Total core recovered (m):** 0.2

**Core recovery (%):** 3.5

**Hard rock:**
  Depth (mbsf): Not known
  Nature: metabasalt and amphibolite rubble

### HOLE 733D

**Date occupied:** 4 November 1987

**Date departed:** 5 November 1987

**Time on hole:** 45 hr 15 min

**Position:** 33°04.92′S, 56°59.39′E

**Bottom felt (rig floor, m; drill pipe measurement):** 5219.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 5207.9

**Total depth (rig floor, m):** 5242.5

**Penetration (m):** 23.5

**Number of cores (including cores with no recovery):** 3

**Total length of cored section (m):** 8.5

**Total core recovered (m):** 0.47

**Core recovery (%):** 5.5

**Hard rock:**
  Depth (mbsf): 20.0
  Nature: metagabbro
  Measured velocity (km/s): 6.2

**Principal results:** After failing to drill basement on the median tectonic ridge of the Atlantis II Transform (Site 732), we moved to Site 733, located on the west wall of the transform at about 33°05′S, 56°59′E. Peridotite was dredged from this area during the pre-cruise site survey, and several small benches suitable for guidebase deployment are present. Gravels similar to those encountered at Site 732 were not expected at this site, but we hoped to find peridotite exposed on fault scarps on the transform wall. The main objective of this site was the same as at Site 732: to drill a deep reentry hole in peridotite to determine the lithology and physical properties of mantle material in a major fracture zone.

*JOIDES Resolution* dropped a beacon at Site 733 at 1351 hr on 31 October 1987. (All times are local unless stated otherwise.) A television/sonar survey of the transform wall located two suitable drilling sites: a flat, sedimented bench in about 4483 m of water and a small, sediment-filled trough about 700 m farther down the slope in about 5208 m of water.

Four holes were drilled in these two locations, the deepest of which penetrated 23.5 meters below seafloor (mbsf). Holes 733A, 733B, and 733C are located on the upper bench and were test holes drilled a few meters apart. A total of 0.29 m of material was obtained for an average recovery of 1%. Hole 733D, drilled in the lower trough, was washed to a depth of 15 m and then drilled to 23.5 mbsf.

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

The material recovered from Holes 733A, 733B, and 733C consists entirely of fragments of foliated metagabbro and amphibolite, none of which were actually cut by the bit. The size and shape of the fragments indicate that they represent talus deposits, not basement. Foliated metagabbro, amphibolite, and minor basalt were recovered in Hole 733D. Although a whole-round piece of foliated metagabbro was recovered from this hole, it probably came from a boulder in the talus pile, rather than from basement.

The foliated metagabbros and amphibolites were subjected to high-temperature plastic deformation and recrystallized under amphibolite facies conditions. Two types of metagabbro are present: a green variety composed chiefly of amphibole and plagioclase and a brown variety that contains predominantly pyroxene and plagioclase. We believe that the protoliths for both varieties were orthopyroxene-rich ferrogabbro. The amphibolite is strongly foliated and consists of amphibole, plagioclase, and epidote. In the metabasalt, actinolite replaces most of the mafic minerals and some of the groundmass plagioclase. Chlorite and epidote are absent, which suggests upper-greenschist to lower-amphibolite facies conditions of metamorphism.

The metagabbros have remanent magnetic intensities similar to those of fresh and altered gabbro from the Mid-Atlantic Ridge, but their initial susceptibilities are much lower. The stable magnetic inclinations from both oriented samples are $-20°$; however, this has little significance because the core was probably recovered from a boulder in the talus overlying basement at this site.

Measured grain densities of the metagabbros are 2.87 and 2.96 g/cm$^3$, within the range of expected values. However, the compressional-wave velocities (6.14–6.24 km/s) are somewhat higher than those for metagabbros from other fracture zones. Variability may be due to differing types or amounts of alteration or to varying proportions of microcracks.

Thermal conductivities range from 1.98 to 2.16 W/m/K and vary systematically when measured parallel or normal to the foliation. The mean conductivity of 2.10 W/m/K is typical for diabase and gabbro. We believe that the small observed anisotropy reflects the preferred mineral orientations.

Because basement was not reached in these holes and drilling conditions were not promising, another site was selected for a test spud-in. *JOIDES Resolution* departed Site 733 at 2130 hr on 5 November.

## BACKGROUND AND SCIENTIFIC OBJECTIVES

A primary goal of Leg 118 was to sample an *in-situ* section of upper mantle peridotite in the Atlantis II Fracture Zone. The first attempt to spud into basement on the median ridge of the transform at Site 732 failed because the ridge crest is mantled by an unknown thickness of rubble or breccia. Consequently, Site 733 was selected for a television/sonar survey and test spud-in to locate a drillable outcrop of serpentinized peridotite. Site 733 is located on the west transform wall at 33°05′S, 56°59′E (Fig. 1), in an area where several dredge hauls recovered peridotite during the pre-cruise site survey. We hoped that peridotite might crop out along fault scarps on the transform wall and that small benches might be present on which the guidebase could be deployed. We also expected that the rubble or breccia covering the floor of the transform and the crest of the median ridge might be less abundant on the transform walls. The main objectives of this site were the same as those at Site 732: to drill a deep reentry hole in peridotite for determining lithology and physical properties of mantle material in a major fracture zone.

## GEOLOGIC AND TECTONIC SETTING

Site 733 is located on the west wall of the Atlantis II Fracture Zone at 33°05′S, 56°59′E (Fig. 1). In this area, the transform wall has a relief of about 2200 m, measured from the break in slope at the top to the valley floor. Several flat, elongated benches appear to mark the intersection of a cross structure with the transform wall. North of this structure, the slope of the wall is considerably lower than average, and the upper slope break is farther west. From several dredge hauls just north of Site 733, abundant peridotite and lesser amounts of basalt and diabase were recovered. The area was selected for closer investigation and drilling because of (1) its proximity to those dredge hauls, (2) the presence of flat benches suitable for guidebase deployment, and (3) the absence of landslide morphology.

Two television/sonar survey lines were run downslope across several benches identified from the pre-cruise site survey Sea Beam map. The surveys revealed slopes largely covered with rubble and minor sediment and relatively flat benches covered with uniform, fine-grained sediment. Two locations were selected for test spud-ins: one on a bench at about 4500 m water depth, the other in a sedimented trough at about 5200 m. Both of these sites were topographically suitable for guidebase deployment. We were unable to locate good bare-rock sites; however, we believed that basement might occur at shallow levels beneath the sedimented areas.

## OPERATIONS

### Introduction

Site-survey data for this general region, acquired in October 1986 (*Conrad* 27-09 cruise, H. Dick, pers. comm., 1987), formed the primary basis for selecting this site. We did not expect to encounter the type of sedimentary rubble on the west wall of the transform that plagued drilling at Site 732. Sea Beam bathymetry data from the site survey showed several small topographic benches, 0.5 to 1 km wide, perched on the otherwise steep slope of the west wall of the transform in this region. We believed that the existence of such benches would assure sufficiently flat locations for deployment of the hard-rock guidebase, if conditions were otherwise appropriate. The beacon location was planned to include several such benches at depths of about 4200, 4500, and 5200 m, which were within range for a detailed survey. The site survey included two dredge hauls (DR-34 and DR-35), located on the wall 3 to 4 nmi to the north, from which mostly peridotite was recovered. Thus, we believed that this area offered good opportunities for drilling and for establishing a deep hole in ultrabasic rock.

### Approach to Site 733

As on the approach to Site 732, the seismic system that was streamed behind the ship was the primary source of bathymetric data for comparison with the Sea Beam maps, as the higher-frequency depth sounders of the ship are practically inoperative at normal ship speeds. We approached the site from the north at 5 to 6 kt, under global positioning system (GPS) navigation control, and a small track pattern (Fig. 2) was surveyed to establish continuity with the Sea Beam contour map. The topographic benches of possible interest for drilling were crossed, and we determined before dropping the beacon that the generally north-south trending contours of the Sea Beam map were displaced to the east by about 0.3 to 0.4 min of longitude, with respect to GPS navigation. Continuity in the north-south direction was more difficult to determine, but it was probably less that 0.5 min of latitude.

At the completion of the brief 1.5-hr survey, the beacon (SN-413) was dropped at 1400 hr (5.5 hr after leaving Site 732), 31 October 1987, at 33°05.30′S, 56°58.87′E. We determined that the beacon depth was 4075 m by observing it with the television/sonar. This depth was somewhat less than that estimated from the ship's seismic profiling system (Fig. 3).

### Television/Sonar Survey

Television/sonar surveys to determine the geological nature of the bottom and its lateral variability occupied about 10 hr.

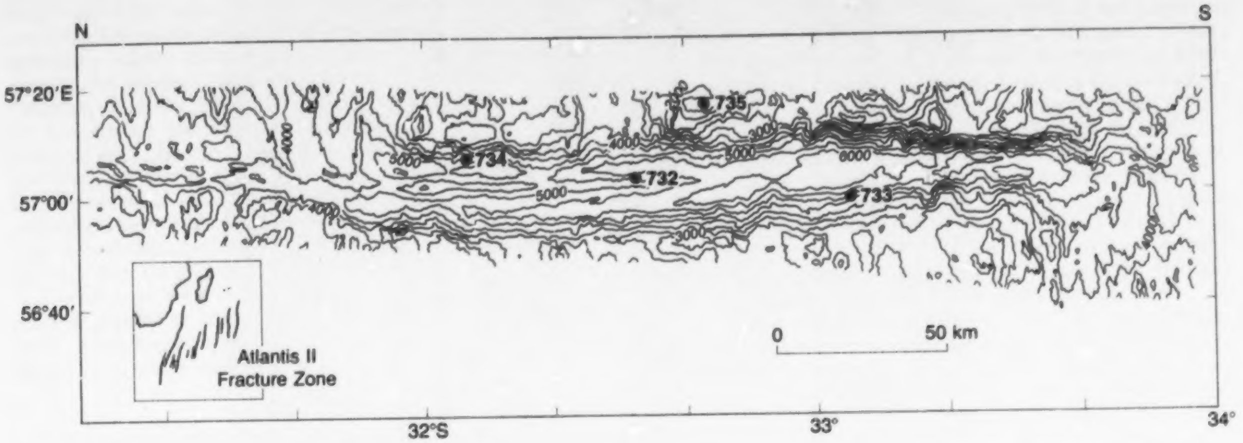
N
S
57°20′E
57°00′
56°40′
4000
3000
734
4000
5000
732
735
3000
5000
6000
733
3000
0
50 km
Atlantis II
Fracture Zone
32°S
33°
34°

Figure 1. Bathymetry map at 500-m contour intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing Leg 118 drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

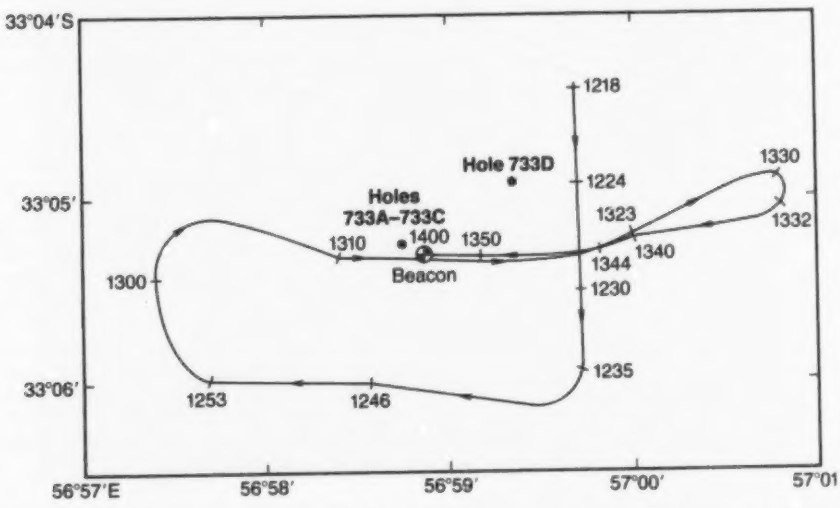
33°04′S
33°05′
33°06′
1218
1224
Hole 733D
Holes
733A–733C
1330
1323
1332
1310
1400
1350
1340
1344
Beacon
1300
1230
1235
1253
1246
56°57′E
56°58′
56°59′
57°00′
57°01′

Figure 2. Ship track line followed before deployment of beacon at Site 733 on 31 October 1987. Times along track are local (UTC + 4 hr). Drill-hole locations are also shown.

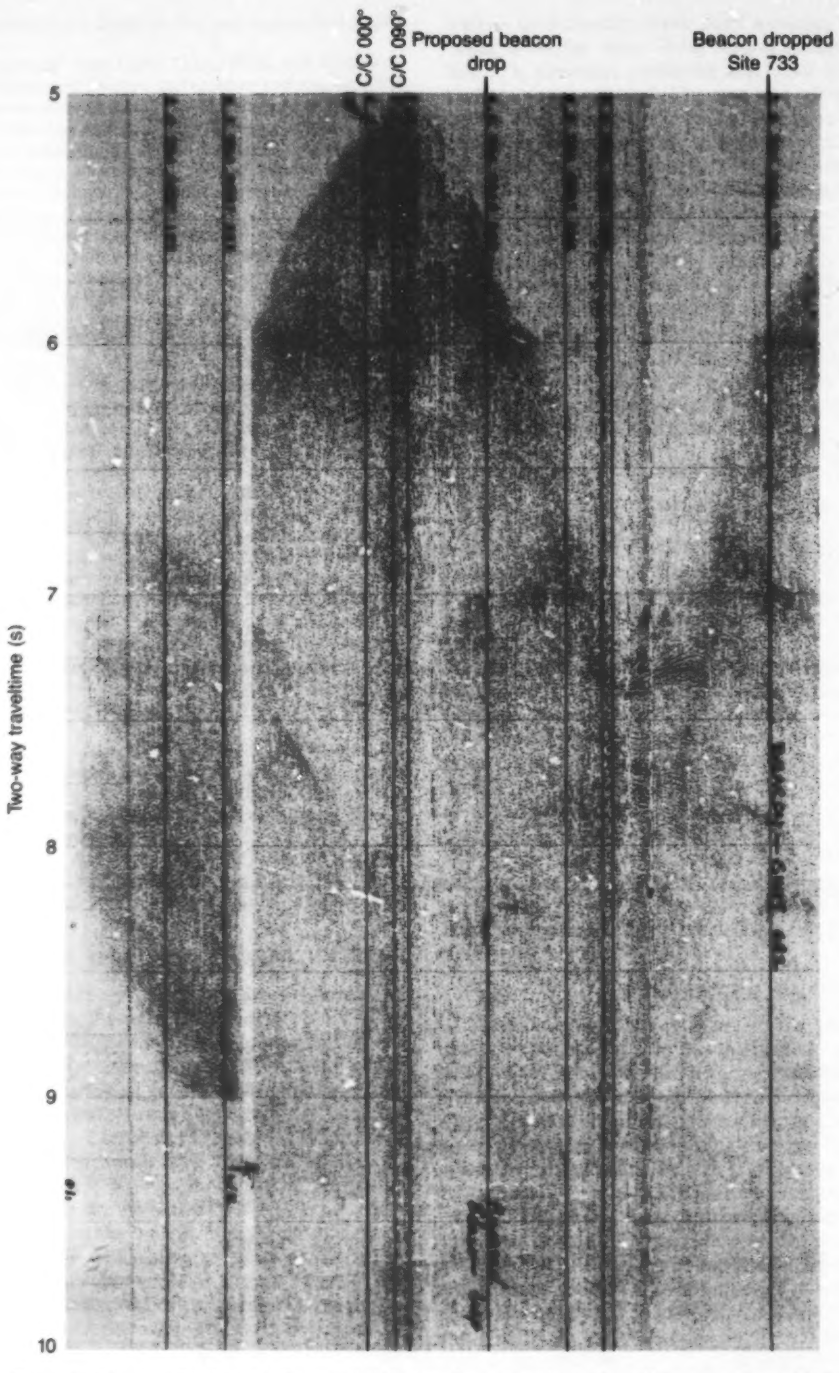

Figure 3. Seismic-reflection profile recorded during the approach to Site 733 between about 0825 and 1000 hr (UTC), 31 October 1987. Note that the initial part of the recording (until 0838 hr) is reversed as a result of a wrong recorder switch setting. Time interval of recording after each "shot" is between 5 and 10 s, and ship's speed was about 5 to 6 kt.

Methodology and techniques used were the same as those described in the Site 732 "Operations" section (this volume). At Site 733, the survey tracks were configured differently for several reasons. First, topographic contours are not oriented exactly north-south, but rather are aligned somewhat east of south and are associated with an increase in width toward the north between walls of the transform in this region. To maintain the television/sonar near the bottom, while avoiding contact with any irregularities along the track, we found it desirable to run the profile lines downslope. Also, the weather was relatively rough at the time of the survey, and the configuration of the ship's winch at the moon pool required us to align the ship with the stern heading in the direction in which the survey lines were run. Fortunately, all these constraints were operationally compatible with each other during the survey, so that we were able to perform the survey efficiently.

Two nearly parallel survey lines, about 4 km in length and separated by 400 to 500 m, were run in a southwest-northeast direction on opposite sides of the beacon (Fig. 4). These profile lines crossed the benches we expected to find from Sea Beam maps and otherwise showed relatively steep slopes (25° to 35°). Sediments, rubble, and large boulders in various locations were seen on the benches. Some of the benches, especially the one identified at about 5200 m, showed uplifted topography (as much as 100 m) and large rounded boulders (dimensions up to 15 m) on their outer lips, then dropping off to steep slopes below. The steep slopes between or below the benches commonly have exposures of massive rock or rubble. Some of the massive rock and large boulders have relatively planar surfaces and angular intersections, although smooth surfaces and rounded large boulders also are common.

Several holes were drilled at each of two sites: one on the bench at a depth of about 4500 m and the other at 5200 m (Table 1). At each hole drilling was stopped by rubble or by a slow rate of penetration, and core recovery was minimal.

### Hole 733A

The positive displacement coring motor with a C-4 bit was picked up, and pipe was lowered to the seafloor. The television/sonar failed; it took 11 hr to repair it. Later, while the television/sonar was being lowered again, the on-bottom beacon failed, forcing us to launch the standby beacon (SN-353). However, approximately 20 min after its launch, the beacon's frequency changed and the signal became unreliable. The original beacon (SN-413) then began to recover, but 14 hr later it failed again, and a third beacon (SN-411) was deployed. This one landed 800 m north of the ship, but because of its distance provided only marginal positioning capability. Fortunately, the original beacon (SN-413) then began to function again.

Eventually, dynamic-positioning personnel concluded that the two operating beacons were being knocked down by a bottom current and that their full signal was not reaching the ship. The second beacon (SN-353) apparently suffered an unknown electronic failure.

The bottom was sighted by the television/sonar at 4494 meters below rigfloor (mbrf). A core was cut to 16.6 meters below seafloor (mbsf) in 3 hr (Table 1). The hole was stable except for an overpull of 60,000 lb at 10 mbsf. Four runs with the wireline were required to latch the core barrel; a piece of rubber from the drill-pipe stabbing guide had jammed in the latch finger, preventing us from engaging the overshot. Fortunately, the same piece of rubber had jammed the core-barrel fishing neck in the overshot, which resulted in our recovering the barrel. While fishing for the core barrel, cuttings apparently entered the mud motor, making circulation impossible. The bit was raised above the mud line, which fortunately caused the blockage to fall out. No core was recovered.

### Hole 733B

The bit tagged bottom at 4498 mbrf. The hole was stable but drilling was very difficult. The hole was cored to 4.3 mbsf in 11.25 hr (Table 1). A total of 0.09 m of metagabbro and amphibolite was recovered.

### Hole 733C

One 5.7-m-long core was cut in 11.75 hr (Table 1). A total of 0.2 m of metabasalt and amphibolite was recovered. We decided to move to another site in an attempt to find rock that could be drilled more easily.

### Hole 733D

The next location was another sediment-filled basin, about 700 m down the transform wall from Holes 733A through 733C. We observed from the television/sonar that the bit touched a soft seafloor at 5219 mbrf. The bit took little or no weight for the first 15 mbsf that was washed (Table 1). The next 5 m were drilled at a reasonable rate of penetration. Extremely hard material was then encountered. From the first core at 15–22 mbsf, we recovered 0.41 m of gabbro, but the second core (at 22–23.5 mbsf) contained almost nothing. After 23 hr of rotation, the hole was abandoned, 8.5 m into the hard material. After 44 hr of rotation, the bit reached the surface completely destroyed.

Should ODP return to the west wall site, the area around Hole 733D should be considered an operating area. The 15 m of sediment offers the opportunity for a casing wash or drill-in. Sediments do not appear to contain rocks that might fall into the hole, and the formation below is stable but very hard.

Most of the drilling at Site 733 was slow. This may reflect in part the apparently widespread occurrence of the strongly foliated and recrystallized metagabbro and amphibolite, but more likely is a consequence of the low weight (5000 to 10,000 lb) that could be applied to the bit in these shallow, nearly bare-rock, holes.

Because of the lack of success in finding massive outcrops of easily drilled peridotite on the west wall, the shipboard scientific party elected to move to a site on the east wall (Site 734), where peridotite had been dredged. *JOIDES Resolution* departed Site 733 at 2130 hr on 5 November 1987 and traveled about 60 nmi north and a little east to Site 734.

## LITHOSTRATIGRAPHY

Metagabbro, amphibolite, and basalt were recovered in three of the four holes drilled at Site 733. Drilling in Hole 733D washed through 15 m of soft sediments, and the television camera showed at least a few centimeters of sediment at each of the other holes. One foliated amphibolite was recovered in Core 118-733B-1D, and a similar amphibolite and an altered basalt were recovered in Core 118-733C-1D. The foliation in the first amphibolite is defined by alternating layers of green amphibole and plagioclase; the protolith is assumed to have been an amphibolitized gabbro, but the only remaining minerals of igneous origin are plagioclase porphyroclasts. The second amphibolite recovered was oriented vertically in the core barrel and has a foliation dipping about 80°. It also had an amphibolitized gabbroic protolith. The first clearly cored igneous or metamorphic samples were recovered in Core 118-733D-1D, in which a 20-cm-long section of medium-grained, two-pyroxene metagabbro was recovered above about 20 cm of a coarse, two-pyroxene metagabbro or metamorphosed gabbronorite (Fig. 5).

The gabbroic samples are intensely deformed and highly recrystallized, with common deformation twins and stretched and fractured grains. Foliation in the coarse gabbro dips 45°, as does the stretching lineation within the foliation. The transition from medium- to coarse-grained gabbro at 20–22 cm in Core 118-733D-1D may derive from an original layering, but may also reflect greater strain in the finer-grained part.

Two angular pebbles were recovered in Core 118-733D-2D: one a fine-grained metabasalt having an amphibolitized matrix and one a foliated amphibolite. These pebbles were not cored and we do not know their position relative to the metagabbro. A few fragments of amphibolitized metagabbro, one cut by a

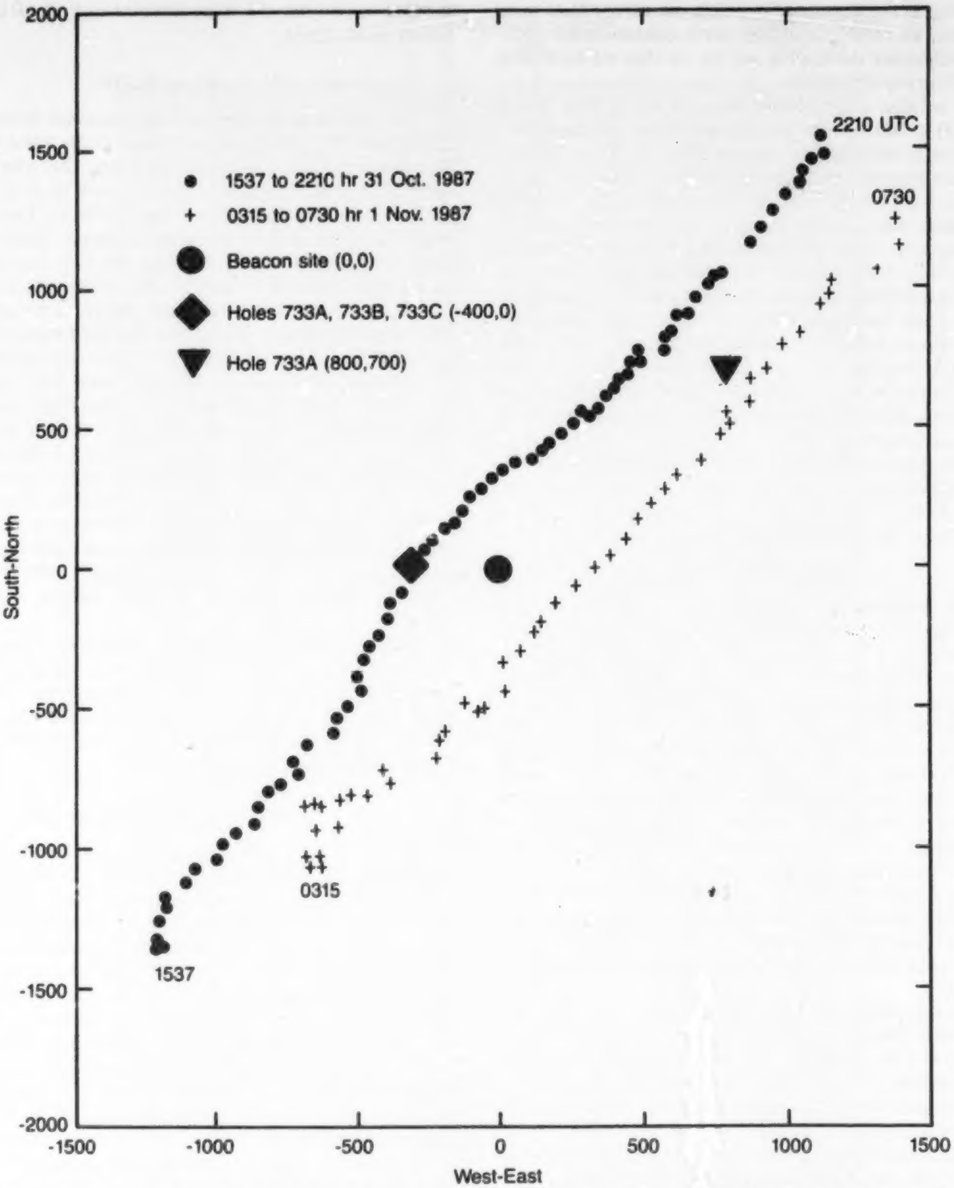

Figure 4. Plot of navigation for television/sonar survey at Site 733. Symbols are positions at nominal 5-min intervals over various time periods (UTC) during survey, as indicated. The beacon site is located at 33°05.30′S, 56°58.87′E, and drill-hole locations are as shown. Axis dimensions in meters from beacon.

**Table 1. Site 733 coring summary.**

| Core | Date (Nov. 1987) | Time (local) | Total depth[a] (m) | Depth (mbsf) | Length advanced (m) | Length cored (m) | Length recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| 118-733A-1D | 2 | 2300 | 4494.0-4510.6 | 0-16.6 | 16.6 | 16.6 | 0 | 0 |
| 733B-1D | 3 | 1555 | 4498.0-4502.3 | 0-4.3 | 4.3 | 4.3 | 0.09 | 2.1 |
| 733C-1D | 4 | 0115 | 4498.0-4503.7 | 0-5.7 | 5.7 | 5.7 | 0.20 | 3.5 |
| 733D, Wash | | | 5219.0-5234.0 | 0-15.0 | 15.0 | 0 | 0 | — |
| 733D-1D | 5 | 0115 | 5234.0-5241.0 | 15.0-22.0 | 7.0 | 7.0 | 0.41 | 2.7 |
| 733D-2D | 5 | 2200 | 5241.0-5242.5 | 22.0-23.5 | 1.5 | 1.5 | 0.05 | 3.3 |
| [b]733D-3B | 5 | 2200 | 5242.5-5242.5 | 23.5-23.5 | 0 | 0 | 0.01 | — |

[a] Determined from drill pipe length below rig floor.
[b] As fragments recovered from bit; not cored.

Figure 5. Foliated metagabbro from Core 118-733D-1D (Piece 3B).

small basaltic dikelet, were recovered from the bit at Hole 733D (Core 118-733D-3B).

## PRIMARY MINERALOGY

### Introduction

Samples from Site 733 include cored, foliated metagabbro (Sample 118-733D-1D-1, 0-46 cm, Pieces 1, 2A, 2B, 3A, and 3B) and a number of randomly collected fragments of metabasalt (Sample 118-733C-1D-1, 0-7 cm, Piece 1), foliated metagabbro and amphibolite with a gabbro protolith (Samples 118-733B-1D-1, 0-9 cm, Piece 1; 118-733C-1D-1, 10-20 cm, Piece 2; 118-733D-2D-1, 0-4 cm, Piece 1; and 118-733D-3B-1, 0-5 cm, Piece 1), and amphibolite with protolith unclear (Sample 118-733D-2D-1, 5-8 cm, Piece 2).

All these samples were metamorphosed at temperatures sufficient to produce hornblende and/or actinolite. Very minor amounts of later low-temperature alteration produced traces of clay minerals. In addition, all samples except the basalt fragment (Sample 118-733C-1D-1, 0-7 cm, Piece 1) are foliated.

The primary igneous mineralogy of the metagabbros, obscured by high-temperature metamorphism, suggests an orthopyroxene-bearing gabbro. The metagabbros can be grouped into predominantly amphibole- and plagioclase-bearing rocks (amphibolites or green metagabbros), and predominantly pyroxene and plagioclase-bearing rocks (brown metagabbros). In the green metagabbros, fractured plagioclase porphyroclasts are the only relicts of primary igneous minerals. The primary mafic minerals have been entirely replaced by amphiboles. In the brown metagabbros, the igneous plagioclase and pyroxene were partially recrystallized during plastic deformation: the temperature conditions during this deformation thus were constrained by the stability of the orthopyroxene plus clinopyroxene plus plagioclase neoblasts.

Here, we describe the primary igneous mineral assemblages of the Site 733 samples and how they were obscured by high-temperature metamorphism under dynamic conditions. In the "Metamorphism and Deformation" section (this chapter), we describe the metamorphic mineral assemblages and the development of the deformation fabric. The metamorphic assemblages can be characterized roughly as pre-deformation, syndeformation, and post-deformation on the basis of petrographic observations and textures.

### Petrography

The samples recovered in Holes 733B, 733C, and 733D are variously deformed and metamorphosed gabbros and a basalt. To establish their protoliths, we found it necessary to interpret the pattern of mineral replacement so that the primary abundances could be estimated from secondary mineral assemblages. The recovered samples can be divided into two categories: (1) samples having relict primary phases coexisting with late low- to medium-grade metamorphic assemblages (termed brown gabbros or foliated metagabbros, see "Metamorphism and Deformation" section, Hole 733D, this chapter), and (2) samples having mainly a metamorphic mineralogy (termed amphibolites, see "Metamorphism and Deformation" section, Holes 733B, 733C, and 733D, this chapter). The textures and inferred relationships among relict primary minerals and their metamorphic replacements are presented as follows:

1. *Plagioclase*. This is the most abundant phase in nearly all samples. Replacement minerals are typically plagioclase neoblasts that result from recrystallization under high-temperature deformation (Samples 118-733D-1D-1, 38-45 cm, Piece 3B, and 118-733D-2D-1, 4-7 cm, Piece 2). Small amounts of epidote (Sample 118-733-2D-1, 4-7 cm, Piece 2) and chlorite (Sample 118-733B-1D-1, 38-45 cm, Piece 3B) also replace plagioclase.

2. *Clinopyroxene*. This is the second most abundant phase in the samples. In the gabbroic samples, clinopyroxene porphyroclasts (augite) are partially recrystallized into small neoblasts (probably more diopsidic in composition; Samples 118-733D-1D-1, 35-37 cm, Piece 3B, and 118-733D-1D-1, 14-15 cm, Piece 2A). Amphibole (either hornblende or actinolite, Samples 118-733D-1D-1, 15-23 cm, Piece 2B, and 118-733D-2D-1, 0-4 cm, Piece 1) and lesser quantities of chlorite (Sample 118-733D-1D-1, 35-37 cm, Piece 3B) also replace clinopyroxene or the green hornblende pseudomorphs of clinopyroxene. Clinopyroxene porphyroclasts contain numerous tiny brown amphibole in-

clusions (Samples 118-733D-1D-1, 14-15 cm, Piece 2A; 118-733D-1D-1, 15-23 cm, Piece 2B; and 118-733D-1D-1, 35-37 cm, Piece 3B).

3. *Orthopyroxene*. This is the third most abundant primary phase in the samples examined. Orthopyroxene porphyroclasts (hypersthene) are only slightly recrystallized to fine-grained neoblasts (Sample 118-733D-1D-1, 15-23 cm, Piece 2B). Cummingtonite or tremolite (with some talc?) is the main replacing phase (Sample 118-733D-1D-1, 38-45 cm, Piece 3B). Lesser amounts of magnesian chlorite and rare actinolite also are present (Sample 118-733D-1D-1, 35-37 cm, Piece 3B).

4. *Opaque phases*. Ilmenite and/or titaniferous magnetite are the most abundant primary opaque minerals. They are partly replaced by magnetite, chlorite, sphene, rutile (Samples 118-733D-1D-1, 14-15 cm, Piece 2A, and 118-733D-1D-1, 15-23 cm, Piece 2B), and hematite (Sample 118-733D-1D-1, 38-45 cm, Piece 3B).

5. *Brown amphibole*. This mineral is, by analogy to other oceanic gabbros, probably kaersutitic pargasite or titaniferous hornblende. It is partly recrystallized to pale brown amphibole (Sample 118-733D-1D-1, 1-4 cm, Piece 1), actinolite (Sample 118-733C-1D-1, 10-12 cm, Piece 2), and green hornblende (Sample 118-733D-1D-1, 2-5 cm, Piece 1). We believe that the limpid, dark brown, well-developed amphiboles are of magmatic origin and probably have crystallized from hydrous intercumulus liquids (along with ilmenite). They occur as small blebs in clinopyroxene porphyroclasts or as thin linings at the outermost margins of the prophyroclasts and ilmenite. Some of these amphiboles may have formed contemporaneously with high-temperature metamorphism. This metamorphism allowed small amounts of high-temperature brown amphibole (stable under these conditions) to recrystallize into neoblast mosaics or around the margins of the clinopyroxenes.

Using the information above, the original mineral percentages of the highly altered, as well as the less altered, samples can be estimated (Table 2). The protoliths fall into four groups: (1) gabbronorite, (2) orthopyroxene-poor gabbro, (3) fine-grained microgabbro or diabase, (4) metabasalt. The first two groups are clearly separated in a ternary plot of the modal proportions of original plagioclase, clinopyroxene, and orthopyroxene (Fig. 6 and Table 2).

Gabbronorite protoliths (Group 1) include Samples 118-733D-1D-1, 12-14 cm, Piece 2A; 118-733D-1D-1, 15-23 cm, Piece 2B; 118-733D-1D-1, 38-45 cm, Piece 3B; and 118-733D-2D-1, 0-4 cm, Piece 1. These are mafic to leucocratic (color index [c.i.]: 40-48 and 29-30, respectively), depending on the modal proportion of plagioclase (Figs. 7 and 8). The pyroxene ratio (clinopyroxene:orthopyroxene) varies from 1:1 to more than 3:2. Sample 118-733D-1D-1, 15-23 cm, Piece 2B, contains a conspicuous contact between foliated leucogabbronorite (c.i. = 29) and foliated gabbronorite (c.i. = 48; Fig. 7). The average grain size of the leucogabbronorite is 6 mm and that of the gabbronorite is 2 mm. The leucogabbronorite contains less ilmenite and brown amphibole (0.4 and 0.7 vol%, respectively) than the gabbronorite (2 and 3.5 vol%, respectively; see Table 2). A symplectiticlike intergrowth in orthopyroxene suggests that a small amount of olivine (<1%) may also have been present in the gabbronorite. These data suggest that the contact is a boundary between two cumulate layers. This layering was probably highly transposed by a strong foliation that resulted from high-temperature plastic deformation (see "Metamorphism and Deformation" section, this chapter, and Fig. 8). Phase layering, marked by variations in the abundance of plagioclase, is typical of layered complexes. The occurrence of cumulus orthopyroxene and the low abundance of brown amphiboles and ilmenite suggest that the Site 733 gabbros were derived from a moderately fractionated tholeiitic liquid (low titanium and iron enrichment).

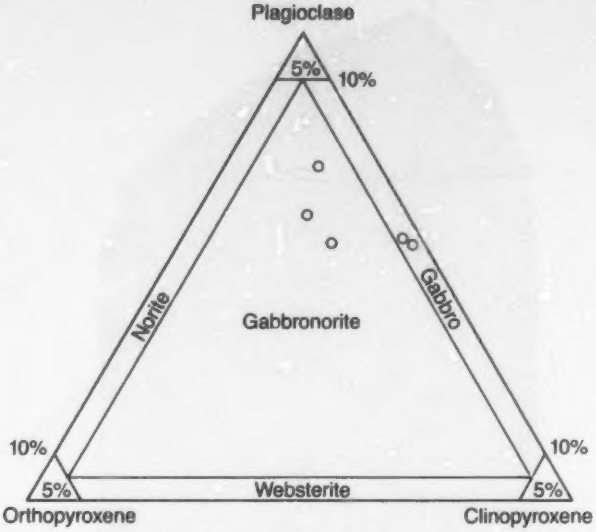

Figure 6. Triangular plot showing the classification of gabbroic rocks. Open circles indicate modal compositions of gabbronorites and gabbros in Table 2. Diagram after Streckeisen (1976).

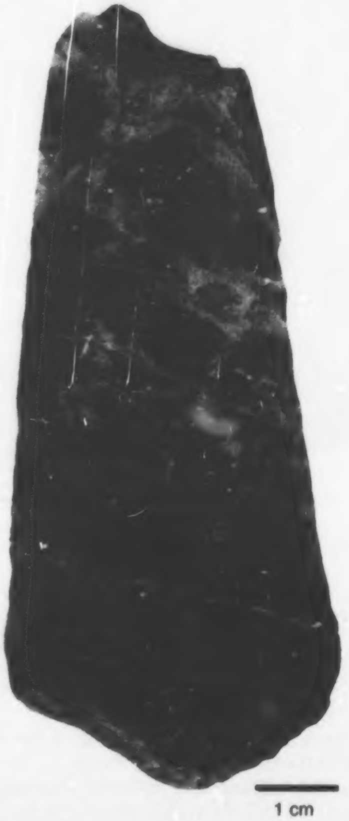

Figure 7. Photograph of Sample 118-733D-1D-1, 15-23 cm, Piece 2B, showing the contact between leucogabbronorite (lower half of the sample) and gabbronorite (upper half of the sample). The point-counted area is located across this contact (see Table 2).

Table 2. Modal compositions of samples from Section 118-733D-1D-1.

| Intervals (cm): | 2-5 | 12-14 | 15-23 Observed mineralogy A | 15-23 Observed mineralogy B | 35-37 |
|---|---|---|---|---|---|
| Relict Primary Mineralogy | | | | | |
| Plagioclase | 12.2 | 17.4 | 38.3 | 6.9 | 14.8 |
| Clinopyroxene | 14.9 | 14.8 | 7.7 | 4.1 | 28.4 |
| Orthopyroxene | 0.5 | 15.2 | 10.3 | 10.5 | 1.4 |
| Opaque phases | — | 0.4 | 0.2 | 1.0 | 0.1 |
| Brown amphibole | 2.9 | 0.2 | 0.7 | 3.3 | 0.9 |
| Secondary Mineralogy | | | | | |
| *Neoblasts* | | | | | |
| Plagioclase | 42.3 | 43.0 | 32.3 | 45.2 | 39.5 |
| Clinopyroxene | 6.9 | 3.5 | 0.3 | 7.5 | 12.8 |
| Orthopyroxene | — | 0.0 | 0.8 | 5.4 | 0.0 |
| *Replacement phases* | | | | | |
| [1] Amphiboles | 18.4 | 4.5 | 8.2 | 14.9 | 1.8 |
| Magnetite | 1.2 | 0.8 | — | — | 0.3 |
| Clay, chlorite, other phases | 1.1 | 0.2 | 1.0 | 0.8 | 0.0 |
| Original Primary Mineralogy | | | | | |
| Plagioclase | 54.5 | 60.6 | 70.6 | 52.1 | 54.3 |
| Clinopyroxene | 39.4 | 20.4 | 17.2 | 26.5 | 42.7 |
| Orthopyroxene | 3.2 | 18.2 | 11.1 | 15.9 | 2.0 |
| Ilmenite | — | 0.4 | 0.4 | 2.0 | 0.1 |
| Brown amphibole | 2.9 | 0.2 | 0.7 | 3.5 | 0.9 |
| Color index | 45.5 | 39.4 | 29.4 | 47.9 | 45.7 |

[1] Includes mostly actinolite and lesser amounts of cummingtonite and green hornblende.

Note: Points counted by thin section: 2000 at 0.4 mm spacing; corresponding piece number to interval of thin section: 2-5 = Pc. 1; 12-14 = Pc. 2A; 15-23 = Pc. 2B; 35-37 = Pc. 3B; color index is the sum of modal mafic and opaque phases.

The gabbro protolith (Group 2) includes four samples: 118-733B-1D-1, 1-4 cm, Piece 1; 118-733C-1D-1, 10-12 cm, Piece 2; 118-733D-1D-1, 2-5 cm, Piece 1; and 118-733D-1D-1, 35-37 cm, Piece 3B. The gabbros are exclusively mafic rocks (c.i. = 46-55) composed of plagioclase, clinopyroxene, and accessory orthopyroxene (Fig. 9). The modal contents of brown amphibole and ilmenite are lower than for the gabbronorites (<2.9 and <0.1 vol%, respectively). In these gabbros, the pyroxene ratio is high (13:1 to 22:1) and relatively constant. The mineralogical data suggest that the gabbros represent mafic layers in a cumulate sequence composed largely of gabbronorite. Primary mineral assemblages suggest a formation depth of 3 to 5 km (Cann, 1979).

A single sample (Sample 118-733D-2D-1, 4-7 cm, Piece 2) of fine-grained mafic rock makes up Group 3. This sample is highly recrystallized and metamorphosed with no relict primary phases. We believe that the percentage of brownish-green hornblende reflects the pyroxene content of the protolith. The grain size of the rock (0.015-0.13 mm) and its metamorphic minerals suggest that the protolith was a fine- to medium-grained microgabbro or a diabase that crystallized at a shallower level than the metagabbros of Groups 1 and 2.

The one sample in Group 4 (Sample 118-733B-1D-1, 0-3 cm, Piece 1) is a porphyritic metabasalt containing abundant green-brown, actinolitic hornblende. However, its primary texture is very well preserved. Plagioclase (10 vol%) and olivine pseudomorphs (initially 2 vol%) are set in a previous clinopyroxene-rich groundmass. This sample obviously originated at a higher level than the gabbronorites, gabbros, and probably the microgabbro (or diabase).

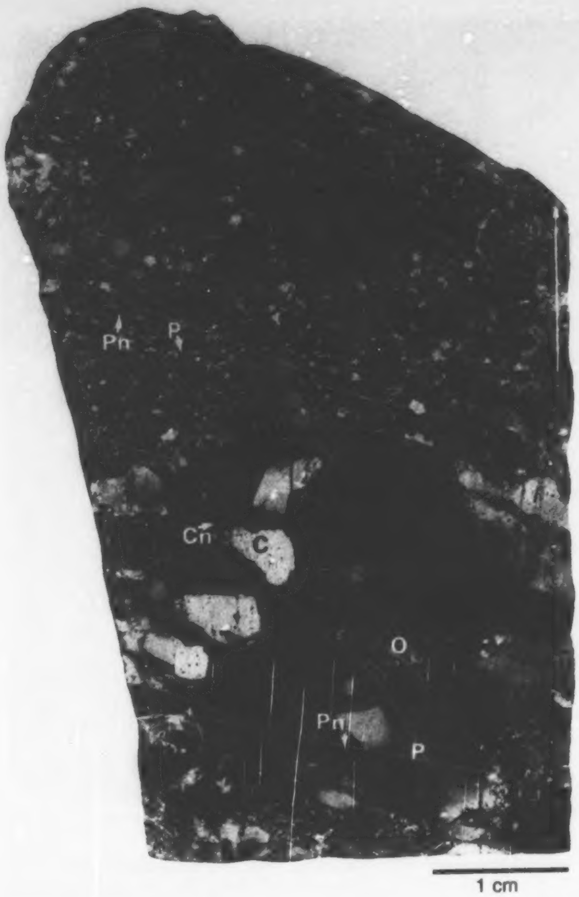

Figure 8. Photograph of the entire thin section from Sample 118-733D-1D-1, 15-23 cm, Piece 2B. P = plagioclase porphyroclasts, Pn = plagioclase neoblasts; C = clinopyroxene porphyroclasts, Cn = clinopyroxene neoblasts; O = orthopyroxene porphyroclasts. The arrow points toward the top of the core. The bar scale is 1 cm long. Note the contact and the strong deformation in the upper part of the sample.

## METAMORPHISM AND DEFORMATION

In the green metagabbros (Samples 118-733B-1D-1, 1-4 cm., Piece 1; 118-733C-1D-1, 10-12 cm., Piece 2; and 118-733D-3B-1, 0-5 cm, Piece 1), the igneous pyroxenes of the protolith are entirely replaced by large crystals of pale green to brownish-green amphibole. Some pale green to brownish-green hornblende pseudomorphs preserve the cleavage of the original igneous clinopyroxene (Fig. 10). Within these hornblende pseudomorphs, small blebs of reddish-brown hornblende are optically identical to the hornblende observed in the fresh clinopyroxene of the brown metagabbros. These were interpreted as probably igneous (see "Primary Mineralogy" section, this chapter). Large grains of fibrous cummingtonite (identified optically) probably replace the original igneous orthopyroxene (Fig. 10). The only relicts of the primary igneous mineral assemblage are partly recrystallized and fractured plagioclase porphyroclasts (Fig. 11).

The foliation is defined by stretched crystals of hornblende (Fig. 12) and cummingtonite (Fig. 10). Most of this stretching is

O
Pn
P
Cn
C
1 cm

Figure 9. Photograph of the entire thin section from Sample 118-733D-1D-1, 2-5 cm, Piece 1. Explanation as in Figure 8. The bar scale is 1 cm long. Note the strong deformation and elongation of the crystals.

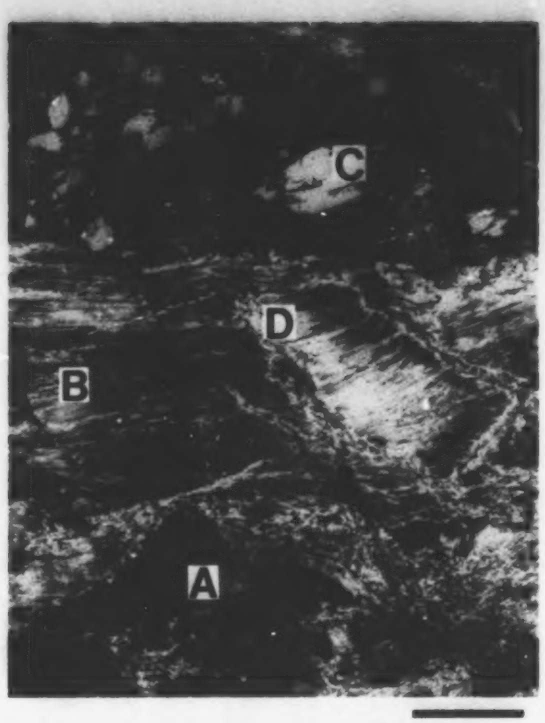

Figure 10. Green metagabbro, Sample 118-733C-1D-1, 10–20 cm, Piece 2. Hornblende pseudomorph of igneous clinopyroxene (A) and cummingtonite replacing igneous orthopyroxene (B). Note the crushed plagioclase (C) and the extensional fractures in the cummingtonite (D). These fractures, filled with a fine-grained amphibole, make a 45° to 60° angle with the foliation (horizontal in the photograph) and indicate that extension occurred in a dextral-shearing regime. Crossed nicols, plane light. Scale bar is 0.5 mm.

accommodated by fractures filled with small grains of a secondary amphibole that is optically identical to the fractured porphyroclasts (Fig. 10). However, fracturing alone cannot account for the preferred orientation of most amphiboles having their long axis in or near the foliation plane (Figs. 10 and 12). Plastic deformation and synkinematic growth of the amphibole porphyroclasts thus may have occurred at an early stage of the deformation. Alternatively, this preferred orientation could have been inherited through pseudomorphic replacement of plastically deformed and stretched pyroxenes. We prefer the first hypothesis because the relict plagioclase porphyroclasts in both samples lack well-developed mechanical twins and do not seem to have been deformed at the very high temperatures required to plastically deform pyroxenes.

The fracturing and partial replacement of amphibole porphyroclasts by smaller grains of an optically identical amphibole was accompanied by crushing (Figs. 10 and 11) and recrystallization (Fig. 12) of the plagioclase porphyroclasts.

In Sample 118-733B-1D-1, 1–4 cm, Piece 1, the next identifiable discrete event is static alteration of the pre-kinematic to synkinematic amphiboles to actinolite (Fig. 12). In Sample 118-733C-1D-1, 10–12 cm, Piece 2, actinolite and chlorite not only fill late crosscutting fractures, but also grow in narrow mylonitic bands, parallel to or slightly oblique to the foliation (Fig. 11). Thus, the deformation of this sample occurred at decreasing temperatures ranging from those of hornblende and cummingtonite stability to those of actinolite and chlorite stability. The geometry of the actinolite plus chlorite mylonitic bands is remarkable: the bands follow an "S"-shaped pattern and have segments both parallel and oblique to the foliation (Fig. 11). The oblique segments are interpreted as shearing segments, with a dextral sense of offset in the thin section (Fig. 11). The same dextral sense of shear is indicated for the earlier, higher-temperature episode by the orientation of extension fractures in the amphibole (Fig. 10).

Sample 118-733D-3B-1, 0-5 cm, Piece 1, is a small pebble of foliated metagabbro that has been intruded by a plagioclase microphenocryst-bearing basalt. The texture of the metagabbro is identical to the other green metagabbros. The crosscutting basalt (dikelet?) is not deformed, and thus its intrusion must postdate the deformation of the metagabbro. The aphanitic matrix of the basalt has been replaced by fine-grained actinolite, similar to the late actinolite replacement observed in the metagabbro. The microphenocrysts are clear, euhedral, and retain igneous twinning.

The fine-grained foliated amphibolite (Sample 118-733D-2D-1, 6–7 cm, Piece 2) contains no relicts of primary igneous minerals. The foliation is marked by crystals of brownish-green hornblende, less than 0.13 mm in size, and by aligned epidote grains, less than 0.01 mm in size. The plagioclase is entirely recrystallized to a mosaic of polygonal grains 0.015 to 0.05 mm in size. All three phases appear to be synkinematic and mutually stable, which suggests an epidote-amphibolite grade of metamorphism. There are no low-temperature alteration minerals.

Characteristic metamorphic assemblages and deformation fabric in the brown metagabbros are discussed next. The brown

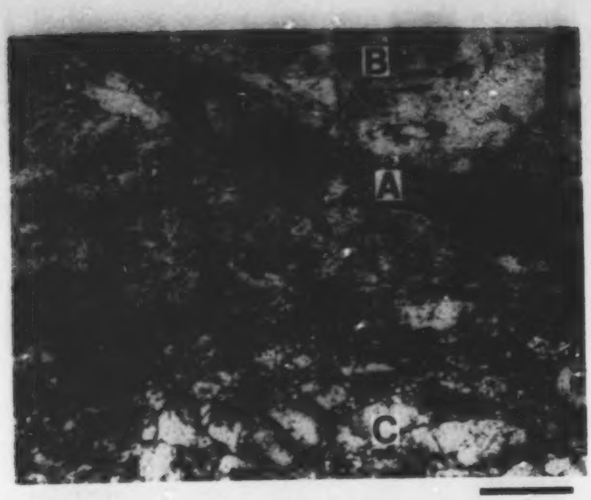

Figure 11. Green metagabbro, Sample 118-733C-1D-1, 10-20 cm, Piece 2. Mylonitic band (A), slightly oblique to the foliation (horizontal in the photograph), and filled with extremely fine-grained actinolite and chlorite. The band is crosscut by a late fracture filled with chlorite (B). Note the crushed and recrystallized plagioclase porphyroclast (C). Crossed nicols, plane light. Scale bar is 0.5 mm.

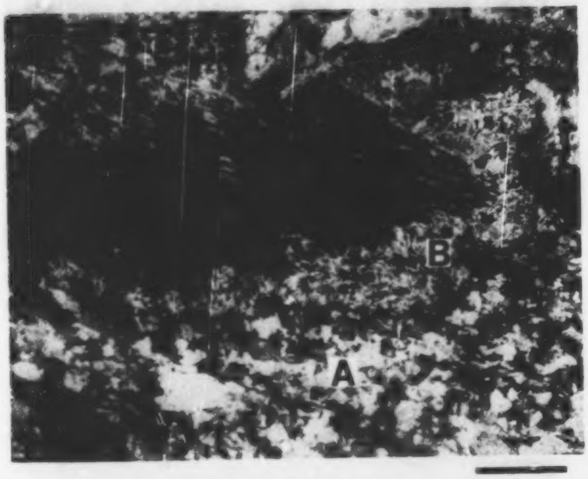

Figure 12. Green metagabbro, Sample 118-733B-1D-1, 0-8 cm, Piece 1. Hornblende crystal elongated in the foliation (horizontal). Note the recrystallized plagioclase (A) and the static alteration of the hornblende rims to actinolite (B). Crossed nicols, plane light. Scale bar is 0.5 mm.

metagabbros (Samples 118-733D-1D-1, 0-46 cm, Pieces 1, 2A, 2B, 3A, and 3B; 118-733D-2D-1, 0-4 cm, Piece 1) all contain porphyroclasts of plagioclase, orthopyroxene, and clinopyroxene, which we interpret as relicts of primary igneous minerals (see "Primary Mineralogy" section, this chapter). These porphyroclasts are plastically deformed and partly recrystallized in polygonal grains. The recrystallized grains themselves are often deformed; thus, the recrystallization is a synkinematic process. The recrystallized assemblage, orthopyroxene plus clinopyroxene plus plagioclase ± brown hornblende, points to high deformation temperatures under anhydrous to slightly hydrous conditions.

A pervasive gneissic foliation and lineation is defined by the elongation of the relict porphyroclasts and of clusters of recrystallized grains. In the two available oriented pieces (Samples 118-733D-1D-1, 14-24 cm, Piece 2B, and 118-733D-1D-1, 32-44 cm, Piece 3B), the foliation dips 45° to 60°, and the lineation appears to dip steeply in the foliation plane.

Igneous plagioclase is as much as 70% recrystallized (mean size of neoblasts: 0.15 mm) and displays tight deformation twins (Fig. 13). Relicts of primary plagioclase are ribbon-shaped porphyroclasts (Fig. 14) and elongated in the foliation. The constant orientation of the mechanical twins relative to the foliation in these ribbon-shaped grains (mechanical twins and foliation make a 50° to 80° angle: see Fig. 14) indicates a strong preferred crystallographic orientation.

The igneous clinopyroxene is 10% to 50% recrystallized (mean size of neoblasts: 0.15 mm), often kinked, and mechanically twinned (Fig. 15). The clear, recrystallized grains cluster around the porphyroclasts and form trails parallel to the foliation. Clear polygonal domains within the clinopyroxene porphyroclasts similarly may be secondary in origin.

The recrystallization of igneous orthopyroxene is limited (about 1%-2% at the most); intracrystalline deformation was the dominant mechanism during the plastic deformation of this mineral. As a result, the orthopyroxene is extremely stretched in the foliation plane (Fig. 16) and shows well-developed preferred crystallographic orientation. In most grains, the (100) intracrystalline slip plane, marked by exsolution lamellae (probably of clinoenstatite), lies near the foliation plane (Fig. 16). The recrystallized orthopyroxene grains (less than 0.1 mm in size) cluster around the porphyroclasts (Fig. 16), or in narrow shear zones parallel to the foliation and cutting through the stretched orthopyroxene porphyroclasts.

Anhedral relicts and blebs of brown hornblende, interpreted as probably igneous (see "Primary Mineralogy" section, this chapter), are locally preserved in the clinopyroxene porphyroclasts. Brown hornblende also can be found as rims around the clinopyroxene porphyroclasts or as interstitial blebs in the clusters of recrystallized clinopyroxenes. These interstitial blebs are themselves sometimes recrystallized into small polygonal grains. These recrystallized grains are metamorphic rather than igneous; they are contemporaneous with the growth of the pyroxene neoblasts during high-temperature plastic deformation.

The relict cores of the clinopyroxene porphyroclasts contain primary igneous cleavage and are filled with inclusions of brown hornblende and opaque grains. Some of the opaque grains (probably ilmenite or titanomagnetite) are replaced by rods and needles of red rutile. The replacement of the titanium oxide phase by rutile instead of sphene is consistent with high-grade metamorphism (Laird, 1982).

Subsequent to the high-temperature plastic deformation, the pyroxenes and brown amphiboles of the brown metagabbros were locally replaced by green amphiboles. Clinopyroxene was replaced by green hornblende and orthopyroxene by a pale amphibole identified optically as cummingtonite (Fig. 17). The replacement appears static; for example, a large crystal of cummingtonite having bent cleavages is in fact a pseudomorph of a deformed orthopyroxene. The green hornblende and cummingtonite crystals are themselves locally replaced by actinolite or actinolitic hornblende. The replacement of pyroxene by amphibole is usually confined to the crystal rims or to crosscutting fractures. The extent of this replacement is greatest near crosscutting veins filled with euhedral green hornblende (Fig. 18). The late shears or fractures within the orthopyroxene are lined with cummingtonite and magnetite. The centers of the larger fractures are filled with green, fibrous actinolite (Fig. 17). The margins of the orthopyroxenes similarly have inner coronas of

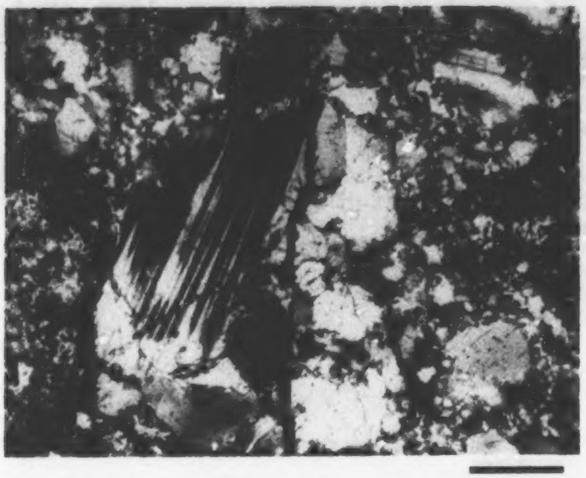

Figure 13. Brown metagabbro, Sample 118-733D-1D-1, 0–7 cm, Piece 1. Partly recrystallized plagioclase porphyroclast having mechanical twins. Crossed nicols, plane light. Scale bar is 0.5 mm.

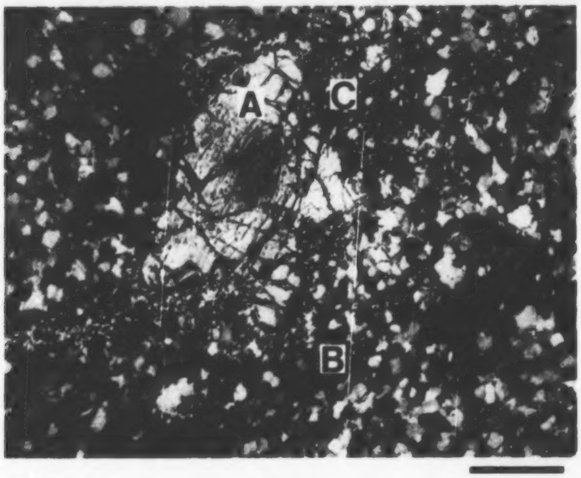

Figure 14. Brown metagabbro, Sample 118-733D-1D-1, 14–25 cm, Piece 2B. Orthopyroxene porphyroclast (A) having tails of recrystallized orthopyroxene (C), in a matrix of recrystallized plagioclase. Note the ribbon-shaped relict (B) of a plagioclase porphyroclast and its mechanical twins. Crossed nicols, plane light. Scale bar is 0.5 mm.

cummingtonite and outer coronas of actinolite. Trace amounts of chlorite lie along the boundary between amphibole and plagioclase segregations. These minerals could have formed during brittle fracturing at temperatures lower than those of cummingtonite stability. Alternatively, this assemblage could represent a cogenetic metasomatic front along the grain boundaries. In any case, this nonpervasive, static, middle-grade metamorphism appears linked to the introduction of a fluid phase into the metagabbros. Fluids were introduced to grain boundaries through fractures and veins that crosscut the plastic deformation fabric.

In the metabasalt Sample 118-733C-1D-1, 0–3 cm, Piece 1, the only surviving mafic mineral is represented by a few rounded phenocrysts of olivine (Fig. 19). The groundmass pyroxene crystal and the other mafic phenocrysts (augite and perhaps olivine) are replaced by green actinolite (Fig. 19). Some of the groundmass plagioclase similarly has been replaced by actinolite or actinolitic hornblende. The minimum grade of this pervasive metamorphism is upper greenschist and probably lower amphibolite, as no evidence of replacement of the calcic plagioclase pheno-

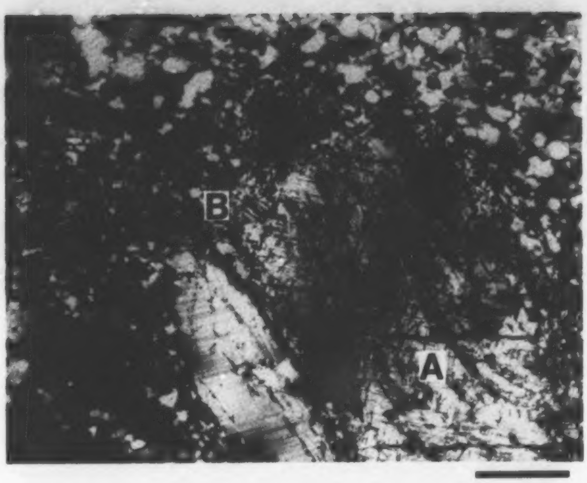

Figure 15. Brown metagabbro, Sample 118-733D-1D-1, 8–13 cm, Piece 2A. Kinked clinopyroxene porphyroclast (A) having a tail of recrystallized clinopyroxene (B). Note the recrystallized plagioclase matrix. Crossed nicols, plane light. Scale bar is 0.5 mm.

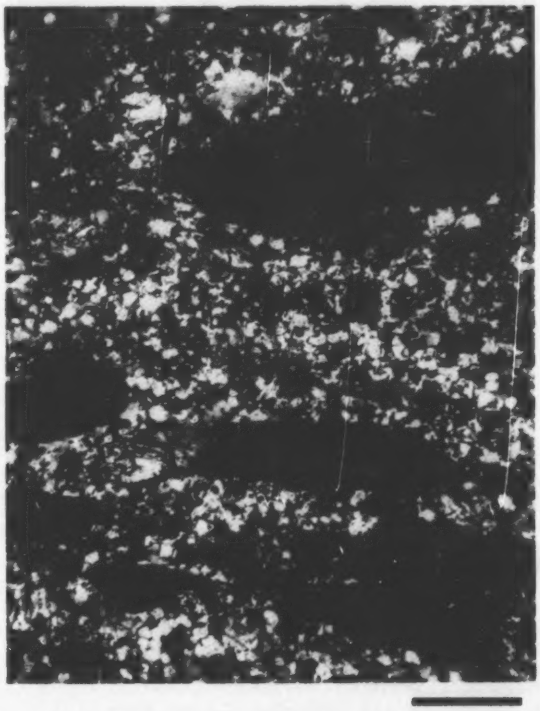

Figure 16. Brown metagabbro, Sample 118-733D-1D-1, 14–25 cm, Piece 2B. Orthopyroxene porphyroclasts stretched in the foliation (horizontal). The (100) slip plane of the orthopyroxene grains, marked by exsolution lamellae (probably of clinoenstatite), are slightly oblique to the foliation: this indicates a dextral sense of shear. Crossed nicols, plane light; Scale bar is 0.5 mm.

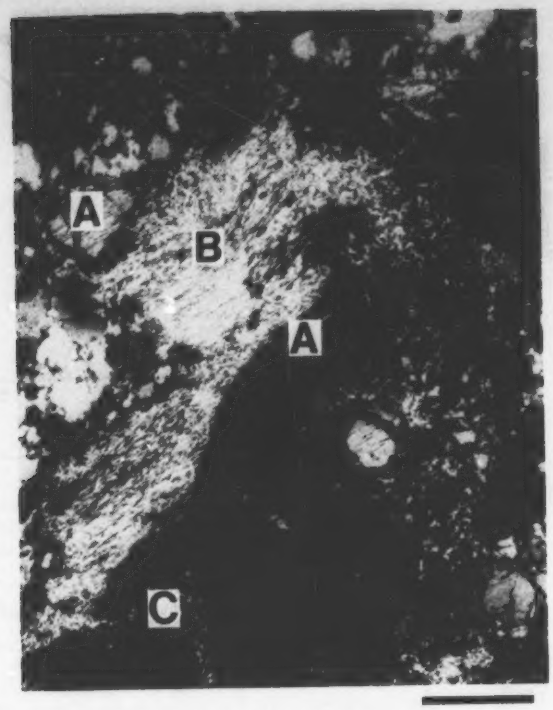

Figure 17. Brown metagabbro, Sample 118-733D-1D-1, 8-13 cm, Piece 2A. Replacement of orthopyroxene (A) by cummingtonite (B). Small fractures (C) in the orthopyroxene are filled with green amphibole (cummingtonite and/or actinolitic hornblende) and opaques. Crossed nicols, plane light. Scale bar is 0.5 mm.

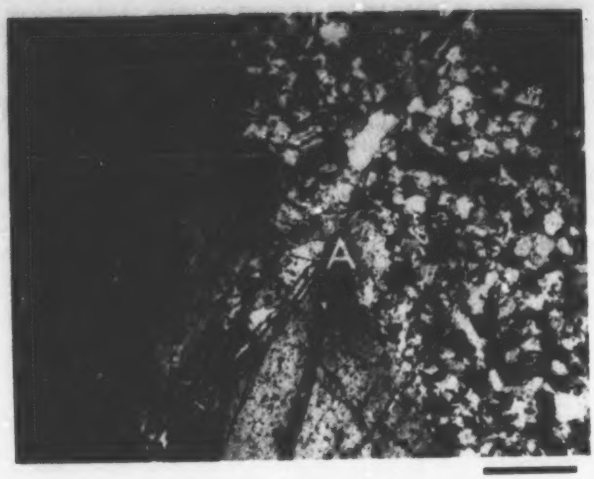

Figure 18. Brown metagabbro, Sample 118-733D-1D-1, 14-25 cm, Piece 2B. Late cross-cutting vein filled with green hornblende (A) in porphyroclastic and recrystallized plagioclase. Crossed nicols, plane light. Scale bar is 0.5 mm.

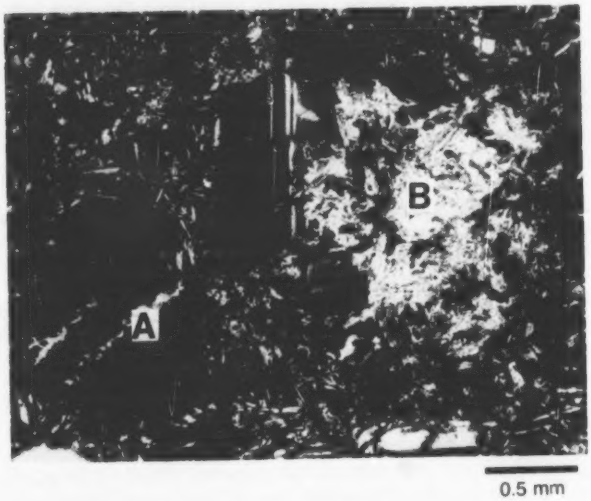

Figure 19. Metabasalt, Sample 118-733C-1D-1, 0-7 cm, Piece 1. Fresh olivine phenocryst (A); mafic phenocryst, altered to green actinolite (B). Groundmass of actinolitized clinopyroxene and plagioclase. Crossed nicols, plane light. Scale bar is 0.5 m.

crysts exists (Fig. 19). This metamorphism is similar to that of the glassy basalt intruded into Sample 118-733D-3B-1, 0-5 cm, Piece 1. For this latter sample, the aphanitic mesostasis of the basalt has been replaced by fine-grained actinolite (obvious only adjacent to plagioclase), while the euhedral plagioclase microphenocrysts appear quite fresh.

### Conclusions

On petrographic grounds we believe that the gabbronorites and the gabbros are genetically linked. They were probably produced by crystal accumulation from the fractionation of a tholeiitic liquid. This accumulation presumably occurred in a crustal magma chamber at the spreading ridge axis. The composition of the gabbros suggests closed system fractionation; the rocks are intermediate between magnesian cumulates and ferrogabbros. The cumulate nature of the gabbroic rocks requires a depth of origin of approximately 3-5 km (approximately 1 kb of lithostatic pressure). The paucity of hydrous phases in the high-grade assemblages indicates nearly anhydrous conditions for this plastic deformation event. The differential stress during the plastic deformation was presumably of the order of 1-2 kb, from which maximum pressures of 1-3 kb were probably required for the metamorphism.

Metamorphism of Site 733 gabbros and basalts was predominantly retrograde and was associated with deformation and variable seawater penetration. Initial temperatures of metamorphism may have been higher than 700°C (orthopyroxene plus clinopyroxene plus plagioclase ± hornblende assemblage), but this estimate requires accurate phase chemical data. The formation of abundant secondary amphibole suggests a temperature range of 400°-600°C.

## GEOCHEMISTRY

Two gabbroic rocks from Hole 733D were analyzed by X-ray fluorescence analysis for major oxide compositions and for abundances of some trace elements. The sample preparation technique and analytical procedures are described in the "Introduction and Explanatory Notes" (this volume).

These samples represent two of the gabbro groups established on the basis of thin-section studies (see "Primary Mineralogy" section, this chapter). Sample 118-733D-1D-1, 12-14 cm, Piece 2A, is a gabbronorite and Sample 118-733D-1D-1, 35-37 cm,

**Table 3. Chemical compositions of gabbroic rocks from Hole 733D.**

| Hole: | 733D | 733D |
|---|---|---|
| Section: | 1D-1 | 1D-1 |
| Interval (cm): | 12-14 | 35-37 |
| (in wt%) | | |
| $SiO_2$ | 52.99 | 53.81 |
| $TiO_2$ | 0.46 | 0.53 |
| $Al_2O_3$ | 17.67 | 20.07 |
| $Fe_2O_3$ | 6.62 | 5.24 |
| MnO | 0.14 | 0.11 |
| MgO | 6.97 | 4.53 |
| CaO | 12.51 | 12.14 |
| $Na_2O$ | 2.60 | 3.44 |
| $K_2O$ | 0.06 | 0.06 |
| $P_2O_5$ | 0.01 | 0.02 |
| LOI | +0.19 | +0.33 |
| (in ppm) | | |
| V | 181 | 174 |
| Cr | 112 | 32 |
| Ni | 48 | 30 |
| Cu | 36 | 23 |
| Zn | 44 | 35 |
| Rb | 0.7 | 0.4 |
| Sr | 134 | 172 |
| Y | 13 | 13 |
| Zr | 17.5 | 19.2 |
| Nb | 1.6 | 1.4 |

LOI = Weight loss on ignition.
Note: A weight gain was recorded for both samples.

Piece 3B, is an orthopyroxene-poor gabbro. The actual modal compositions (in volume percent) of these rocks, as determined by point counting, are given in Table 2. Chemical data are listed in Table 3.

Both samples apparently contain only very small abundances of hydroxyl-bearing minerals (amphiboles, clays, etc.) because they gained weight during ignition. The low contents of MgO, as well as chromium and nickel, and the relatively high $SiO_2$ concentrations indicate that both rocks crystallized from evolved liquids.

The trace element abundances were mainly determined by the proportions of the two major cumulus phases, clinopyroxene and plagioclase. Concentrations of highly incompatible elements, such as rubidium and zirconium, are up to eight times lower in the gabbros, compared to the basalts of Site 732. Yttrium, strontium, vanadium, and niobium are less depleted in the gabbros, a result of partitioning in clinopyroxene (yttrium), plagioclase (strontium), and oxide phases (vanadium and niobium; Fig. 20). Although the zirconium/niobium, yttrium/zirconium, and yttrium/niobium ratios of the gabbros were slightly affected by crystal accumulation, the values, especially the high yttrium/zirconium and yttrium/niobium ratios, strongly suggest that the gabbros from Hole 733D crystallized from depleted normal-type mid-ocean ridge basaltic melts similar to the clasts recovered at Site 732 (see "Geochemistry" section, Site 732 chapter).

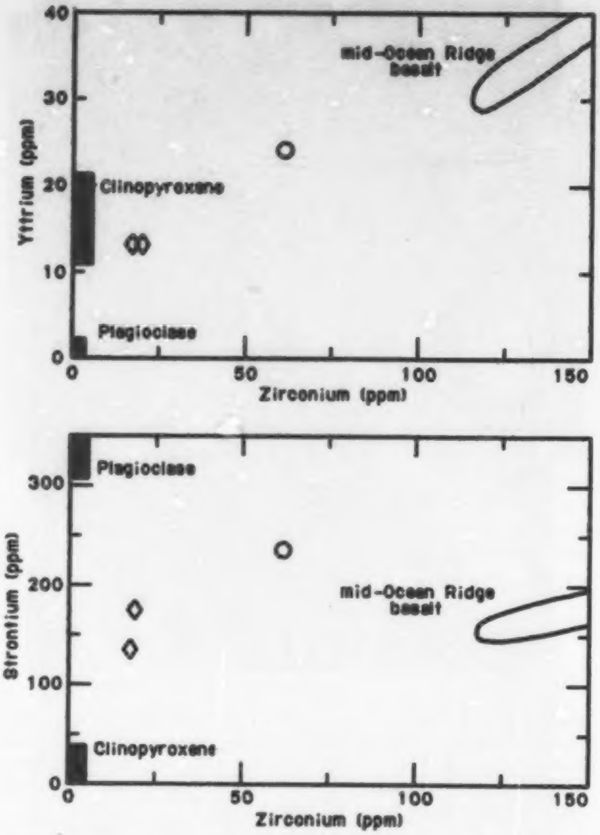

Figure 20. Concentrations of yttrium, strontium, and zirconium in the two analyzed gabbros from Hole 733D (open diamonds). The data for normal Mid-Ocean Ridge basalts and a gabbro (open circle) from Site 732 and estimated concentrations in clinopyroxene and plagioclase in equilibrium with normal Mid-Ocean Ridge basalt liquids are plotted for comparison. The low zirconium contents of the Hole 733D gabbros indicate relatively low amounts of trapped intercumulus liquid, in contrast to the gabbro from Site 732.

Following a procedure outlined by Meyer et al. (in press), the major oxide data were used to calculate the proportions and compositions of cumulus phases as well as the proportions of trapped liquid for both rock types. The procedure assumes that the rock is composed of an equilibrium assemblage of cumulus minerals plus trapped liquid, and that the liquid has a composition that lies along a liquid line of descent. For the rocks investigated, this liquid line is defined by basaltic compositions from the Southwest Indian Ridge (le Roex et al., 1983), with the limitation that only normal-type mid-ocean ridge basalts having zirconium/niobium ratios greater than 17 were used.

Table 4 shows the calculated bulk compositions; the agreement with actual compositions (Table 3) is very good, except for the substantial differences between the observed and calculated $Na_2O$ contents. The calculated cumulus phase assemblage (in weight percent) for Sample 118-733D-1D-1, 12–14 cm, Piece 2A, is 53.3% plagioclase (An 55.3%), 26.1% clinopyroxene (magnesium value of 73.0), and 12.3% orthopyroxene (magnesium value of 68.9), which is in equilibrium with a liquid having a magnesium value of 38.3. The corresponding values calculated for Sample 118-733D-1D-1, 35–37 cm, Piece 3B, are 62.0% plagioclase (An 51.4%), 20.7% clinopyroxene (magnesium value of 71.5), 5.3% orthopyroxene (magnesium value of 67.3), and a magnesium value of 36.6 for the trapped liquid. The calculated proportions of trapped liquid are 8.4% and 12.4%, respectively, in agreement with estimates based on the contents of a strongly incompatible trace element such as zirconium (Fig. 21). Thus, these rocks are mesocumulates. The data inferred from the calculations are typical of mineral assemblages crystallized from evolved mid-ocean ridge basaltic melts and, once again, underscore the evolved nature of the samples investigated. The calculated mineral proportions are consistent with the modal abun-

Table 4. Calculated compositions of gabbroic rocks from Hole 733D (following Meyer et al., in press; see Table 3 for actual chemical analysis).

| Hole: | 733D | 733D |
|---|---|---|
| Section: | 1R-1 | 1R-1 |
| Interval (cm): | 12-14 | 35-37 |
| (in wt%) | | |
| $SiO_2$ | 52.89 | 53.70 |
| $TiO_2$ | 0.46 | 0.51 |
| $Al_2O_3$ | 17.74 | 20.15 |
| $FeO_{tot}$ | 6.02 | 4.79 |
| MgO | 7.14 | 4.70 |
| CaO | 12.60 | 12.22 |
| $Na_2O$ | 3.11 | 3.96 |
| $K_2O$ | 0.08 | 0.11 |
| $P_2O_5$ | 0.03 | 0.04 |

dances determined by point counting (Table 2), if one allows for the fact that a thin section is not necessarily representative of the larger samples taken for major element analysis.

## PALEOMAGNETICS

### Introduction

A shipboard paleomagnetic study was conducted to characterize the magnetic properties and to examine the direction of remanent magnetization in highly deformed and altered crustal rocks from Site 733. Although only two vertically oriented samples were recovered at Site 733, it is nevertheless of interest to compare their magnetic properties with those of other oceanic gabbros.

### Experimental Methods

Minicores of 2.5 cm in diameter and about 1.4 cm long were drilled from the two oriented pieces of core recovered from Hole 733D. Sample 118-733D-1D-1, 12–14 cm, Piece 2A, is a medium-grained gabbro and Sample 118-733D-1D-1, 35–37 cm, Piece 3B, is a coarse-grained, flaser gabbro. Remanent magnetic properties (intensity, inclination, and declination) were measured with a spinner magnetometer (see "Introduction and Explanatory Notes," this volume). ODP hard-rock cores are not oriented azimuthally, and thus declination values are not meaningful when considered independently.

Alternating field demagnetization (AFD) was performed with a single axis demagnetizer (see "Introduction and Explanatory Notes," this volume), and thus required a separate AFD cycle for each orthogonal axis. Both samples were demagnetized until less than 10% of the original remanence remained (Table 5).

On the basis of demagnetization data, Zijderveld plots were used to identify the stable magnetic inclinations ($I_s$). The median destructive field (MDF) was determined from the demagnetization curves and represents the peak field at which 50% of the natural remanent magnetization ($J_0$) was removed. Initial susceptibility ($X_0$) was measured with a commercial susceptibility meter ("Introduction and Explanatory Notes," this volume). The Koenigsberger ($Q$) ratio was calculated from observed values of $J_0$ and $X_0$ using a 1985 value of the Earth's field at this location (0.38 Oe, Merrill and McElhinny, 1983), so that $Q = J_0/(X_0 \times 0.38)$.

### Results

#### *Intensity of Remanent Magnetization ($J_0$)*

$J_0$ values for Samples 118-733D-1D-1, 12–14 cm, Piece 2A, and 118-733D-1D-1, 35–37 cm, Piece 3B, are 0.75 and 0.45 × $10^{-3}$ emu/cm$^3$, respectively. These values are of the same order of magnitude as those obtained from both unaltered and highly altered oceanic gabbros from the Mid-Atlantic Ridge (Fox and Opdyke, 1973) and unaltered gabbros from the Troodos Ophiolite (Pariso and Johnson, in press).

#### *Initial Susceptibility ($X_0$)*

Susceptibility values for Samples 118-733D-1D-1, 12–14 cm, Piece 2A, and 118-733D-1D-1, 35–37 cm, Piece 3B, are 0.29 and 0.66 × $10^{-3}$ cgs units, respectively, and are similar to those obtained by both Fox and Opdyke (1973) and Pariso and Johnson (in press). Both $J_0$ and $X_0$ are a function of grain size and concentration of the magnetic minerals within the rock, and it is likely that the low susceptibility values are a result of the small effective magnetic grain size.

#### *Koenigsberger Ratio (Q)*

$Q$ ratios for the gabbro and flaser gabbro are 68 and 18, respectively. The $Q$ ratio is a measure of the importance of the remanent magnetization with respect to the *in-situ* induced magnetization, and, in this case, there appears to be negligible induced magnetization. However, we are not sure that the recovered samples are representative of the dominant lithologies in this crustal section. Thus, we could make no generalizations about the source of the *in-situ* magnetization for this crustal section.

#### *Alternating Field Demagnetization (AFD)*

The Zijderfeld plots (Figs. 21 and 22) indicate that Sample 118-733D-1D-1, 12–14 cm, Piece 2A, had one component of remanent magnetization and that Sample 118-733D-1D-1, 35–37 cm, Piece 3B, had two components of magnetization. MDF values were determined from the demagnetization curves and were used to judge the stability of magnetization. The MDF value for Sample 118-733D-1D-1, 12–14 cm, Piece 2A, is 300 Oe, which indicates a very stable magnetization. The demagnetization curve for Sample 118-733D-1D-1, 35–37 [illegible] 3B, shows that a soft, secondary component was removed at a peak field of 150 Oe and that the remaining component is also quite stable (MDF = 280 Oe). The secondary component of this sample may have been acquired during drilling because it was heated during removal from the core barrel.

#### *Inclination*

The natural remanent inclinations ($I_0$) for Samples 118-733D-1D-1, 12–14 cm, Piece 2A, and 118-733D-1D-1, 35–37 cm, Piece 3B, are −21° and −46°, respectively. The stable magnetic inclinations ($I_s$) determined for both samples are approximately −20°. Based upon the assumption of a geocentric axial dipole field, the theoretical inclination value for 33°S latitude is −52°. The anomalous inclination values may be explained by one or more of the following mechanisms: (1) tectonic rotation of a crustal block, (2) gravitational displacement and rotation of a large boulder, (3) paleosecular variation, or (4) post-cooling southern drift of the crust from which the sample was taken. Once again, we found it difficult to reach a conclusion based on only two samples, and further studies will be necessary to understand the remanent magnetic properties of the rocks recovered from this site.

## PHYSICAL PROPERTIES

Two cylindrical minicores were cut perpendicular to the splitting plane for shipboard analysis of grain density, porosity, and velocity (Table 6). The small percentage of porosity is associated with microfractures distributed throughout the rock. Grain densities are completely consistent with the mineral proportions and densities. In contrast, the observed compressional wave velocities are lower than expected from the isotropic mineral ve-

Table 5. Remanent magnetic properties for stepwise demagnetization.

| Core/section interval (cm) | Depth (mbsf) | AF (Oe) | CSD (degrees) | Dec. (degrees) | Inc. (degrees) | Intensity (mA/m) |
|---|---|---|---|---|---|---|
| 118-733D-1D-1, 12 | 15.12 | 000 | 4.6 | 350.0 | −21.2 | 750.4120 |
| 1D-1, 12 | 15.12 | 025A | 4.6 | 349.1 | −21.2 | 728.1910 |
| 1D-1, 12 | 15.12 | 050A | 5.9 | 348.5 | −19.3 | 695.4000 |
| 1D-1, 12 | 15.12 | 075A | 6.3 | 347.7 | −20.0 | 660.9790 |
| 1D-1, 12 | 15.12 | 100A | 7.0 | 347.0 | −20.4 | 619.2450 |
| 1D-1, 12 | 15.12 | 150A | 6.2 | 346.5 | −17.3 | 527.9690 |
| 1D-1, 12 | 15.12 | 200A | 7.7 | 345.8 | −18.4 | 461.9980 |
| 1D-1, 12 | 15.12 | 250A | 8.1 | 345.2 | −18.7 | 402.4070 |
| 1D-1, 12 | 15.12 | 300A | 8.4 | 345.3 | −19.1 | 352.9150 |
| 1D-1, 12 | 15.12 | 350A | 8.5 | 345.3 | −18.1 | 309.9240 |
| 1D-1, 12 | 15.12 | 400A | 7.7 | 346.8 | −18.6 | 270.9870 |
| 1D-1, 12 | 15.12 | 500A | 8.4 | 348.0 | −18.8 | 212.1780 |
| 1D-1, 12 | 15.12 | 600A | 8.3 | 348.0 | −19.1 | 168.2290 |
| 1D-1, 12 | 15.12 | 700A | 8.7 | 350.7 | −21.9 | 134.5870 |
| 1D-1, 12 | 15.12 | 800A | 8.7 | 355.0 | −24.8 | 108.7010 |
| 1D-1, 12 | 15.12 | 900A | 6.8 | 11.1 | −38.5 | 94.0149 |
| 1D-1, 35 | 15.35 | 000 | 9.3 | 21.3 | −46.4 | 445.7980 |
| 1D-1, 35 | 15.35 | 025A | 6.1 | 11.3 | −39.3 | 422.0560 |
| 1D-1, 35 | 15.35 | 050A | 4.7 | 7.6 | −32.5 | 385.7800 |
| 1D-1, 35 | 15.35 | 075A | 4.0 | 7.4 | −28.2 | 355.0460 |
| 1D-1, 35 | 15.35 | 100A | 4.3 | 6.9 | −25.4 | 331.8210 |
| 1D-1, 35 | 15.35 | 150A | 4.9 | 6.2 | −22.5 | 291.9200 |
| 1D-1, 35 | 15.35 | 200A | 4.2 | 6.3 | −21.4 | 257.6520 |
| 1D-1, 35 | 15.35 | 250A | 3.8 | 6.7 | −20.1 | 226.9090 |
| 1D-1, 35 | 15.35 | 300A | 4.5 | 6.7 | −20.2 | 204.0300 |
| 1D-1, 35 | 15.35 | 350A | 4.9 | 6.1 | −19.4 | 182.6250 |
| 1D-1, 35 | 15.35 | 400A | 5.4 | 5.2 | −19.8 | 163.6080 |
| 1D-1, 35 | 15.35 | 500A | 5.0 | 6.5 | −18.7 | 130.6780 |
| 1D-1, 35 | 15.35 | 600A | 5.5 | 6.9 | −18.4 | 103.8300 |
| 1D-1, 35 | 15.35 | 700A | 5.4 | 10.0 | −19.9 | 77.7334 |
| 1D-1, 35 | 15.35 | 800A | 7.0 | 7.8 | −20.8 | 60.2040 |

Mbsf = depth below seafloor, including the 15 m of overlying sediment; AF = peak demagnetizing field; CSD = circular standard deviation; Dec. = declination; Inc. = inclination; and Intensity = magnetic intensity.

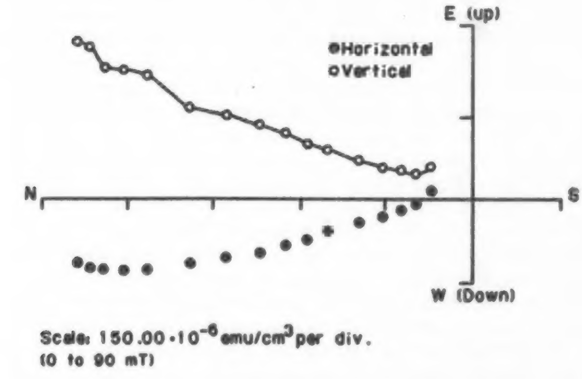

Figure 21. Zijderfeld plot showing the horizontal and vertical magnetic vectors during stepwise demagnetization.

locities and densities (Fig. 23). Three explanations of this discrepancy may apply.

1. The direction in which velocities were measured is not representative of the average $V_p$ of the two rocks measured because of a possible $V_p$ anisotropy.
2. The fracture porosity of the two metagabbros may have reduced the compressional wave velocity. Gabbroic rocks, as well as most other igneous rocks, tend to show an increase in $V_p$ of about 0.2–0.5 km/s (Christensen, 1982), with an increase in pressure that is attributed to the closure of microcracks.
3. The single-crystal velocities used for comparison with the rock velocities are inappropriate for the mineral compositions in the rocks under study. This seems to be unlikely considering the mineral compositions in these rocks.

The principal secondary mineral in these rocks is hornblende (see "Primary Mineralogy" section, this chapter), with only trace amounts (1%–2%) of phyllosilicates. Metagabbros from other fracture zones, such as the Kane and the Oceanographer fracture zones, commonly have velocities that are substantially lower than those determined here, even when they have relatively similar densities (Fig. 24). Alteration to lower metamorphic grade might reduce $V_p$ by replacing the primary minerals with phyllosilicates that have lower $V_p$ (Fig. 23).

Thermal conductivity was measured on one metagabbro sample from Site 733 (Sample 118-733-1D-1, 38–45 cm, Piece 3B). A slab with approximate dimensions (10 × 50 × 70 mm) was cut perpendicular to the plane of gneissic foliation, which inclined approximately 45° to the axis of a continuous 130-mm-long section of core. This slab was ground flat to a 600 grit finish, and thermal conductivity was measured using the needle probe method adapted to a slab sample configuration, as described by Von Herzen and Maxwell (1959) and Vacquier (1985). This technique measures the thermal conductivity (*K*) radial to the probe, excluding the heat transfer parallel to the probe, so that variations in thermal conductivity with probe orientation are rough indicators of anisotropies in conductivity caused by preferred mineral orientations. We observed variations in *K* within the plane of the slab cut parallel to the core axis and perpendicular to foliation (Table 7). Reproducibility of conductivity standards with similar *K* values was within about 0.05 W/m/K and thus the directional variations in *K* are probably real and stem from preferred mineral orientation. Lack of specific information on the thermal conductivity tensors for plagioclase, orthopyroxenes, and clinopyroxenes and the preferred mineral orientations in the sample preclude a more quantitative interpreta-

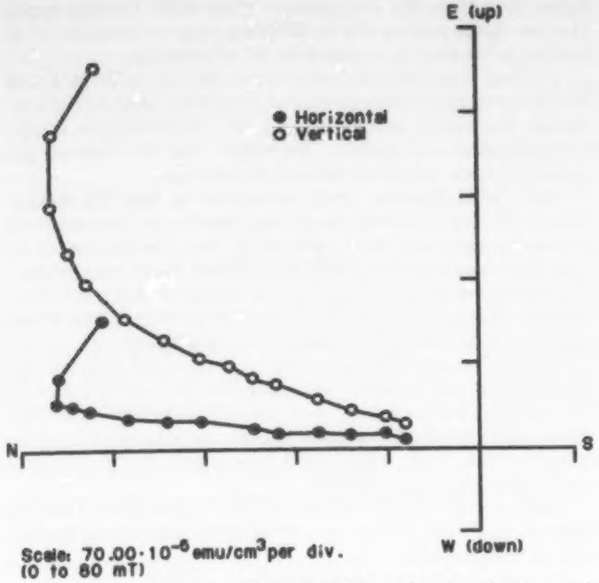

Figure 22. Zijderfeld plot showing the horizontal and vertical magnetic vectors during step-wise demagnetization. Two magnetic components are present, and the curvature between them indicates an overlapping of the coercivity spectra.

**Table 6. Summary of the physical properties of samples recovered from Site 733.**

| Core/section interval (cm) | Texture and lithology | Grain density ($Mg/m^3$) | Porosity (%) | Velocity (km/s) |
|---|---|---|---|---|
| 118-733D-1D-1, 12–14 | Gneissic metagabbro | 2.960<br>[a](2.920) | 0.5 | 6.24<br>[a](6.84) |
| 1D-1, 35–37 | Gneissic metagabbro | 2.870<br>[a](2.810) | 0.4 | 6.14<br>[a](6.66) |

[a] Densities and compressional-wave velocities, in parentheses, calculated from the percentages of minerals (Table 2) and single-crystal properties shown in Figure 24.

tion of these variations in *K* with direction. The mean conductivity of 2.05 ± 0.1 W/m/K is typical of rocks of similar gross mineralogy, such as diabases and gabbros that have *K* values ranging from 1.7 to 2.5 W/m/K (Clark, 1966). These conductivities are low when compared to granites, granodiorites, and ultramafic rocks and reflect the low conductivity of plagioclase feldspar (1.8 ± 0.1 W/m/K, Clark, 1966), which is the predominant mineral in this sample.

## SUMMARY AND CONCLUSIONS

Site 733 is located on the west wall of the Atlantis II transform at about 33°05′S, 56°59′E, in an area where peridotite was dredged during the site survey. Several flat benches in the area offered potential sites for deployment of the hard-rock guidebase, should peridotite be located during test spud-ins. During a television/sonar survey, two areas were identified as potentially suitable drilling sites: a flat, sedimented bench in 4483 m of water and a small sediment-filled trough about 700 m farther downslope in 5208 m of water. No good bare-rock outcrops were located during the survey, but basement was thought to underlie the sedimented areas at shallow levels.

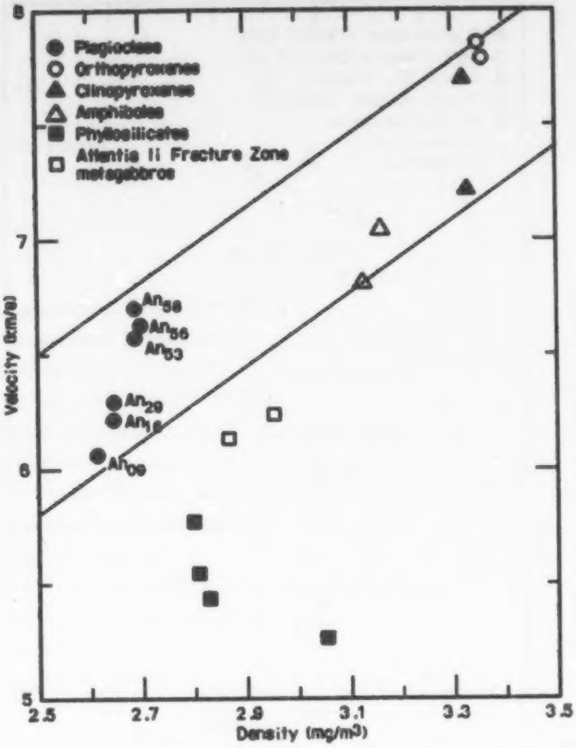

Figure 23. Velocity vs. density systematics for mafic minerals and the data for the two Atlantis II Fracture Zone metagabbro samples. Arrows indicate the likely range of velocity and density correction for fracture porosity. Note the substantially lower velocities for phyllosilicates that would lower bulk velocities for low-grade alteration gabbros. Lines represent the approximate bounds on the velocity and density for the metagabbros, based on the properties of the component minerals. Data from Christensen (1982).

Four holes were drilled in these two locations, the deepest of which penetrated 23.5 mbsf. Holes 733A, 733B, and 733C are located on the upper bench and were test holes drilled a few meters apart. A total of 0.29 m of material was obtained from Holes 733B and 733C for an average recovery of 2.1%. Hole 733D, drilled in the lower trough, was washed to a depth of 15 mbsf and then drilled to 23.5 mbsf. Less than 0.5 m of material was recovered from this hole.

The material recovered from Holes 733B and 733C consists entirely of fragments of foliated metagabbro and amphibolite, none of which were actually cut by the bit. The size and shape of the fragments indicate that they represent talus deposits, not basement. Foliated metagabbro, amphibolite, and minor basalt were recovered in Hole 733D. Although a short whole-round piece of metagabbro was recovered, it probably came from a boulder in the talus pile, rather than from basement.

The foliated metagabbros and amphibolites were subjected to high-temperature plastic deformation and were extensively recrystallized. Two types of metagabbro are present: a green variety composed chiefly of amphibole and plagioclase and a brown variety that contains mostly pyroxene and plagioclase. We believe that the protoliths for both varieties are an orthopyroxene-rich ferrogabbro. The amphibolite is strongly foliated and consists of amphibole, plagioclase, and epidote. In the metabasalt, actinolite replaces most of the mafic minerals and some of the groundmass plagioclase. Chlorite and epidote are absent, which suggests upper greenschist to lower amphibolite facies conditions of metamorphism.

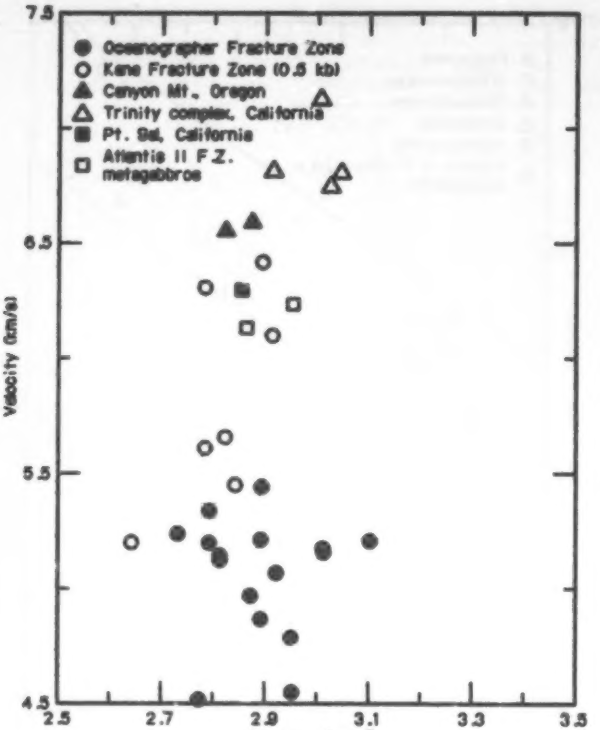

Figure 24. Velocity vs. density data for metagabbros, including the two Atlantis II metagabbro samples under study. Note the significantly lower velocities of metagabbros at various fracture zones, which we interpreted as consequence of lower-grade alteration to assemblages, including phyllosilicates. Data from Christensen (1982).

**Table 7. Summary of variations in thermal conductivity with direction in Sample 118-733D-1D-1, 38-45 cm, Piece 3B.**

| Probe direction | Conductivity (W/m/K) |
|---|---|
| Parallel to core axis | 2.16 |
| Parallel to foliation (45° to core axis) | 2.00 |
| Normal to foliation (−45° to core axis) | 1.98 |

The metagabbros from Hole 733D have remanent magnetic intensities similar to those of fresh and altered gabbro from the Mid-Atlantic Ridge but have much lower initial susceptibilities. The stable magnetic inclinations average from −20°, but this has little significance because the core was probably recovered from a boulder in talus overlying basement.

Measured grain densities of the metagabbros are 2.87 and 2.96 g/cm$^3$, within the range of expected values. However, the compressional-wave velocities (6.14-6.24 km/s) are somewhat higher than those for metagabbros from other fracture zones. The low values may be due to differing types or amounts of alteration or to varying proportions of microcracks.

Thermal conductivities range from 1.98 to 2.16 W/m/K and vary systematically when measured parallel or normal to the foliation. The mean conductivity of 2.10 ± 0.10 W/m/K is typical for diabase and gabbros. We believe that the observed anisotropy reflects preferred mineral orientations.

The television/sonar survey conducted at Site 733 demonstrated that both the steep slopes and benches on the transform wall are covered with talus and rubble. Variable thicknesses of finer-grained sediment have also accumulated on the flat benches. The benches observed at Site 733 are probably fault controlled, but the sedimented trough at the foot of the slope (Hole 733D) may have been formed by slumping or landsliding.

Drilling was very difficult in the loose talus and sediment because of poor hole stability. The unconsolidated sediment seemed to wash away during drilling, and only small, pebble-sized fragments were recovered. Larger boulders, such as the one penetrated in Hole 733D, might have been cored if the sediments were somewhat more coherent.

The complete absence of peridotite in the recovered material suggests that only gabbro and metagabbro are present on this part of the transform wall.

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**Ms 118A-105**

# 5. SITE 734[1]

## Shipboard Scientific Party[2]

### HOLE 734A

**Date occupied:** 6 November 1987

**Date departed:** 9 November 1987

**Time on Hole:** 45 hr 15 min

**Position:** 32°06.83′S, 57°07.81′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3670.7

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3659.6

**Total depth (rig floor, m):** 3678.30

**Penetration (m):** 7.60

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 7.60

**Total core recovered (m):** 0.05

**Core recovery (%):** 0.7

**Hard rock:**
Depth (mbsf): Not known
Nature: serpentinized lherzolite

### HOLE 734B

**Date occupied:** 9 November 1987

**Date departed:** 9 November 1987

**Time on hole:** 16 hr 15 min

**Position:** 32°06.82′S, 57°07.80′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3681.5

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3670.4

**Total depth (rig floor, m):** 3729.0

**Penetration (m):** 47.50

**Number of cores (including cores with no recovery):** 5

**Total length of cored section (m):** 47.50

**Total core recovered (m):** 1.10

**Core recovery (%):** 2.3

**Oldest sediment cored:**
Depth (mbsf): 9.50
Nature: foraminiferal ooze, sand, and gravel
Earliest age: Holocene
Hard rock: gravel component of sediment
Nature: serpentinite, amphibolite, metagabbro, metabasalt, and alteration minerals

### HOLE 734C

**Date occupied:** 9 November 1987

**Date departed:** 9 November 1987

**Time on hole:** 1 hr 30 min

**Position:** 32°06.81′S, 57°07.84′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3706.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3694.9

**Total depth (rig floor, m):** 3725.0

**Penetration (m):** 19.0

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 19.0

**Total core recovered (m):** 0

**Core recovery (%):** 0

### HOLE 734D

**Date occupied:** 9 November 1987

**Date departed:** 9 November 1987

**Time on hole:** 3 hr

**Position:** 32°06.79′S, 57°07.84′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3720.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3708.9

**Total depth (rig floor, m):** 3739.50

**Penetration (m):** 19.50

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 19.50

**Total core recovered (m):** 0.79

**Core recovery (%):** 4.0

**Oldest sediment cored:**
Depth (mbsf): 19.50
Nature: foraminiferal ooze, sand, and gravel
Earliest age: Holocene
Hard rock: gravel component of sediment
Nature: serpentinite, amphibolite mylonite, metagabbro, metabasalt, and alteration minerals

### HOLE 734E

**Date occupied:** 9 November 1987

**Date departed:** 10 November 1987

**Time on hole:** 20 hr

**Position:** 32°06.76′S, 57°07.75′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3746.2

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3735.1

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

**Total depth (rig floor, m):** 3755.70

**Penetration (m):** 9.50

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 9.50

**Total core recovered (m):** 0

**Core recovery (%):** 0

## HOLE 734F

**Date occupied:** 11 November 1987

**Date departed:** 12 November 1987

**Time on hole:** 18 hr

**Position:** 32°06.87′S, 57°08.22′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3436.0

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3424.9

**Total depth (rig floor, m):** 3450.0

**Penetration (m):** 14.0

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 14.0

**Total core recovered (m):** 0.10

**Core recovery (%):** 0.7

**Hard rock:**
Depth (mbsf): not known
Nature: serpentinized peridotite rubble

## HOLE 734G

**Date occupied:** 12 November 1987

**Date departed:** 13 November 1987

**Time on hole:** 38 hr

**Position:** 32°06.87′S, 57°08.24′E

**Bottom felt (rig floor, m; drill pipe measurement):** 3428.5

**Distance between rig floor and sea level (m):** 11.10

**Water depth (drill pipe measurement from sea level, m):** 3417.4

**Total depth (rig floor, m):** 3459.50

**Penetration (m):** 31.0

**Number of cores (including cores with no recovery):** 3

**Total length of cored section (m):** 31.0

**Total core recovered (m):** 5.95

**Core recovery (%):** 19.1

**Oldest sediment cored:**
Depth (mbsf): 23.50
Nature: calcareous and foraminiferal ooze, drill cuttings, and breccia
Earliest age: early Pleistocene
Hard rock: cuttings/breccia component of sediment
Nature: serpentinite, metagabbro, metabasalt, and alteration minerals

**Principal results:** Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S, 57°08′E. The objectives at this site were to sample a section of upper mantle peridotite and to drill a deep basement hole that could be used to conduct downhole geophysical measurements and experiments. Mostly peridotite and dunite with minor basalt were recovered from two dredge hauls done during the pre-cruise site survey in this vicinity. Site 734 was selected for basement drilling because the topography indicated a steep, regular slope for this part of the transform wall without any indication of slumping or landsliding. We hoped that a small, relatively flat bench could be found on which to deploy the hard-rock guidebase. This would allow us to drill into the underlying peridotite.

*JOIDES Resolution* arrived at Site 734 on the morning of 6 November 1987 and dropped two beacons. A television/sonar survey located two areas of basement outcrop: one on the wall of a gully or small canyon at a water depth of about 3750 m and the other about 700 m to the east and about 350 m shallower, probably on a small fault scarp.

Seven holes were drilled at this site: Holes 734A through 734E at the deeper site and Holes 734F and 734G at the shallower site. Significant penetration was achieved only in Holes 734B and 734G (47.5 and 31.0 meters below seafloor [mbsf], respectively). A total of about 8 m sediment containing various clasts of igneous and metamorphic rock was recovered, chiefly from Holes 734B, 734D, and 734G.

Similar sequences of graded sand and gravel, each about 80 cm long, were recovered in Holes 734B and 734D. The grain size in these sequences decreases upward regularly, from pebbles at the base to fine sand at the top. The upper few centimeters in each sequence consist of foraminiferal ooze and sand. Rock fragments in the gravels range up to 3.5 cm long and are angular to subangular. These fragments consist of serpentinite, amphibolite mylonite, metagabbro, and metabasalt. Fragments of aragonite and other alteration minerals, such as prehnite, talc, and tremolite, make up 10% to 15%.

A 6-m-long section of highly disturbed, soupy sand and gravel composed of ultramafic material was recovered in Hole 734G. Based on its soupy nature, lack of stratification, and poorly sorted texture, we believe that this material represents drill cuttings or sediment that slumped into the hole from above.

The uppermost sediments in Holes 734B and 734D contain abundant, well-preserved foraminifers and calcareous nannofossils; the nannofossils are dated as Holocene. The sediments recovered from Hole 734G are probably early Pleistocene in age, somewhere between 1.37 and 1.88 Ma.

Most of the recovered clasts in the sediment consist of highly metamorphosed and deformed peridotite and metagabbro; a few are composed of amphibolite mylonite, metabasalt, and carbonate-cemented breccia containing amphibolite and serpentinite clasts. The ultramafic rocks are foliated lherzolite and harzburgite composed of about 75% serpentine, 10% magnetite, and 10% to 15% relict primary olivine, orthopyroxene, and clinopyroxene. Two of the ultramafic samples are cut by calcium silicate veins composed chiefly of prehnite. In the metagabbros, the original plagioclase and clinopyroxene have been largely replaced by clay minerals, albite, actinolite, and prehnite. Both the mylonite and breccia are almost devoid of primary minerals.

The television/sonar survey conducted at this site revealed a steep slope (about 24°) heavily mantled with talus and sediment. Basement crops out only along steep cliffs on the walls of gullies and canyons or on fault scarps. None of the recovered core can be unequivocally interpreted as basement, but the abundance of ultramafic clasts and fragments suggests that such material is present beneath the rubble and talus.

Site 734 was abandoned after numerous unsuccessful attempts to sample basement. We encountered considerable difficulty in starting a hole on such a steeply sloping cliff. For those holes where spud-in was successful (Holes 734B and 734G), drilling conditions were poor; thus, we decided the site was unsuitable for deployment of the hard-rock guidebase.

## BACKGROUND AND SCIENTIFIC OBJECTIVES

While searching for an outcrop of peridotite on which the hard-rock guidebase could be deployed for drilling a deep basement hole, we moved to Site 734 on the east wall of the Atlantis II Transform (Fig. 1). After considering several possible locations on the transform walls, we selected Site 734 because the topography indicated a steep, regular slope with no sign of landsliding. From two dredge hauls in this vicinity performed during the pre-cruise site survey, peridotite and dunite were recovered; thus, we expected these steep slopes to provide good locations for outcrop. Structural models for development of the trans-

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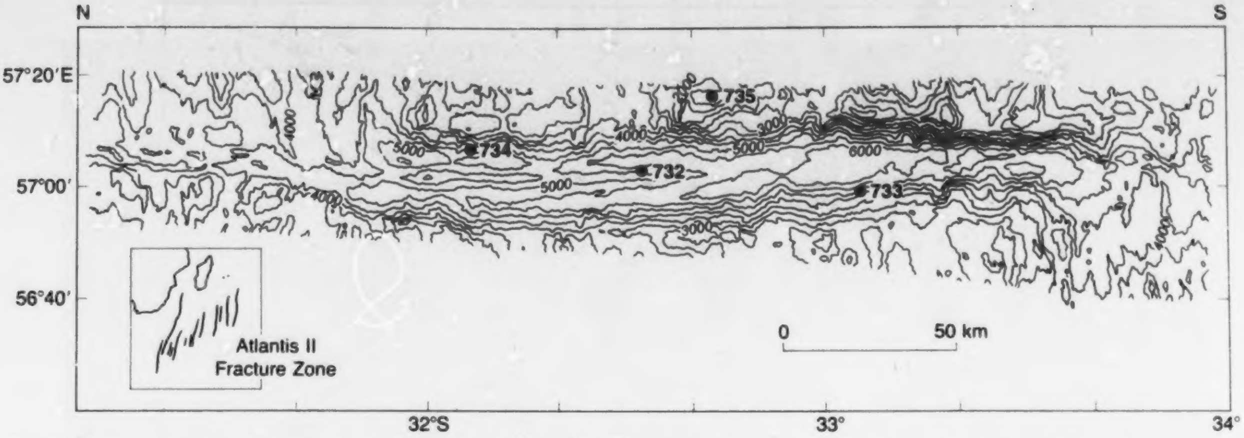

Figure 1. Bathymetric map at 500-m contour intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing Leg 118 drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

form wall suggested a series of steep normal faults separated by small, relatively flat benches on which a guidebase could be deployed (H. Dick, pers. comm., 1987).

Two television/sonar survey lines run down the transform wall revealed bare-rock outcrops on the northern survey line. Two sites along this line were then selected for more detailed study. We found that at the lower site (at a water depth of about 3750 m), outcrops of igneous rock occurred on the wall of a gully or small canyon. The upper site, about 700 m to the east and about 350 m shallower, has massive outcrops along a small fault scarp.

The objectives at this site were (1) to sample a section of mantle peridotite and (2) to drill a deep hole in basement that could be used to perform downhole geophysical measurements and experiments.

## GEOLOGIC AND TECTONIC SETTING

Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S and 57°08′E (Fig. 1), on a straight section of the transform wall, where there is no indication of landsliding or slumping. This part of the wall has a relief of about 2500 m over a horizontal distance of about 5.5 km, which results in an average slope of about 24°. Based on its location in magnetic anomaly 2, this part of the transform has an age of about 3 Ma.

One structural model of the transform walls suggests that the slopes are composed of a number of steep normal faults separated by relatively small, flat benches (H. Dick, pers. comm., 1987). From two dredge hauls conducted during the pre-cruise site survey, peridotite, dunite, and a small amount of basalt were recovered (H. Dick, pers. comm., 1987). The steep slope of this wall near the location of Site 734, suggested that outcrops would be less likely to be covered with talus and rubble than was the case at Site 733.

A television/sonar survey performed in the vicinity of Site 734, however, showed that the transform wall was heavily mantled with talus and finer-grained sediment. Basement was seen to crop out in only two areas: on the walls of a gully or small canyon and along a small fault scarp at a relatively high position on the transform wall. These outcrops consist of coherent, massive rock, probably peridotite, as this was the dominant rock type recovered by drilling at this site.

## OPERATIONS

### Introduction

Site 734 was selected to contrast with the previously occupied sites of Leg 118. It is located on the relatively steep (25° to 35°) east wall of the transform in relatively young crust created at the northern spreading center adjacent to the transform. We hoped that there would be significantly less rubble and breccia on this steep wall than we encountered at the previous two sites, and that basement rocks might crop out at the surface. The site was selected using data from the site survey for Leg 118 (H. Dick, pers. comm., 1987). The Sea Beam bathymetric maps created during that survey allowed us to select a location with a relatively uniform slope over a depth range from about 2 to 6 km, including a small bench at its southern extremity. Two dredge hauls (DR-18 and DR-19), recovered at the northern end of this site, consisted primarily of peridotite and dunite, respectively, rock types which we wished to drill during this leg.

### Approach to Site 734

Site 734 was approached from the south along the transform valley as the ship transited from the previous site. An S-shaped track pattern (Fig. 2) was used to locate the appropriate depths along the north-south lineated east wall where we could deploy the location beacons. At this site we decided to drop two beacons about 2 nmi apart in a north-south direction so as to survey more of the transform wall than was possible at previous sites. The separation distance between beacons was approximately the maximum for which they could be tied together navigationally, using the ship's acoustic positioning system.

As with previous approaches, the ship was slowed to about 5-6 kt, with the seismic profiling system operating so that reliable bottom depths were recorded. Global positioning system (GPS) navigation was generally available for the approach, although not as continuously as we had expected. After dropping beacon 1 at a location determined by GPS navigation and bathymetry, a hiatus in GPS coverage during the survey caused the ship to turn eastward prematurely toward the anticipated deployment location of beacon 2, which was quickly rectified by changing to a more northerly course after re-acquiring GPS navigation. The Sea Beam bathymetric contour map appeared nearly coincident with depth soundings acquired during the drill ship's approach, and the beacons were dropped at the planned

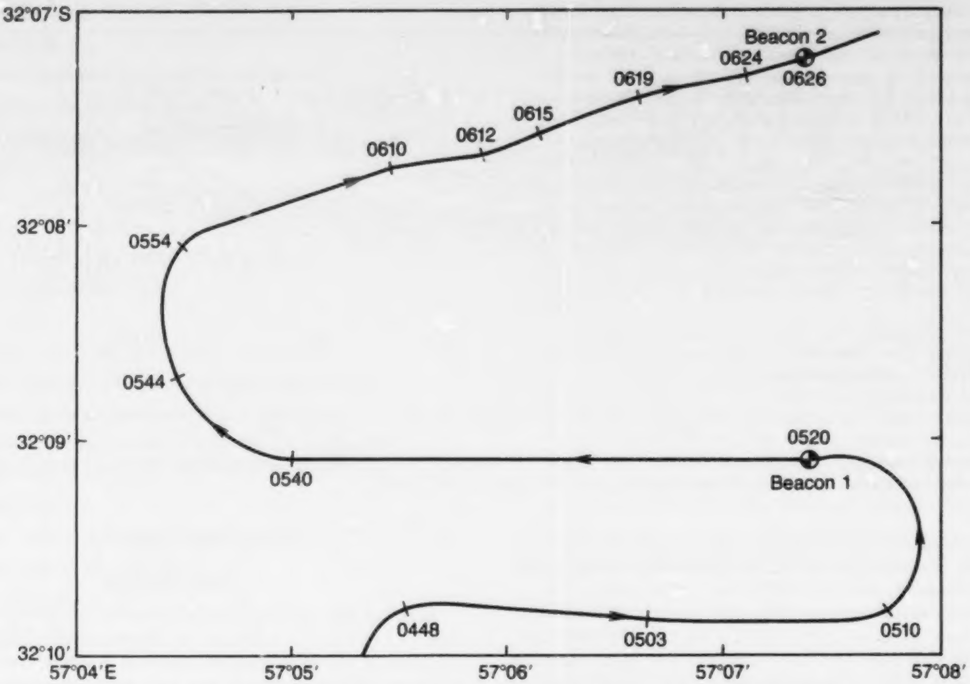

Figure 2. Ship track line followed for deployment of two beacons at Site 734 on 6 November 1987. Times along track are local (UTC + 4 hr). Beacon 1 is located at 32° 09.1'S, 57°07.5'E, and beacon 2 is located at 32°07.2'S, 57°07.4'E. Drill holes are located outside the boundaries of this plot.

locations (Fig. 2) in water depths of about 4.4 and 4.1 km, respectively, for beacons 1 and 2 (Fig. 3).

### Television/Sonar Survey

The survey lines consist of three profiles run downslope (two of which are shown in Fig. 4), as on previous surveys during Leg 118, to minimize the possibility that the instrument might be caught on bottom irregularities. The first and northernmost profile, between bottom depths of about 3300 and 4400 m, was the most interesting because we observed several rock outcrop areas that were promising drilling targets. These were located at depths of about 3400 and 3750 m on the slope, the latter apparently on the side of a canyon or fault approximately subparallel to the survey track. The other two profiles were not as useful or interesting because they revealed sedimented or rubbly rock surfaces over their entire lengths, which made them problematical as drilling targets. The middle profile extended over bottom depths ranging from about 3300 to 4300 m, and the southernmost one (not shown in Fig. 4) ranged between a depth of about 3900 and 4900 m. A relatively flat bench was also observed in this profile. One drilling difficulty foreseen from the surveys was that most rock outcrops occurred on steep slopes, whereas less steep slopes were invariably obscured by sediment or rubble. This initial survey took 33.75 hr, including the time for camera deployment.

After drilling some of the initial holes at this site, two minisurveys were performed around the outcrop areas located along the first survey line (Fig. 5). One of these surveys better defined the regions of outcrop at the shallowest site at a depth of 3400, and the other investigated a fault scarp along which occurred relatively sharp lateral transitions (only a few tens of meters) from sediment/rubble to extremely steep (up to vertical) canyon walls with massive rock outcrop. These two surveys were done by lowering the TV/sonar once, which took about 13 hr, including time for camera deployment. Several holes were drilled at each of two locations on the fracture zone wall at water depths of about 3750 and 3400 m (Table 1, Fig. 5), generally resulting in minimal recovery.

### Hole 734A

We decided to use the positive displacement coring motor for the test spud-in. The bottom hole assembly (BHA) was composed of a 10 1/2 in. bit, coring motor, crossover, five 8 1/4 in. drill collars, crossover, one 7 1/4 in. drill collar, crossover, and six stands of 5 1/2 in. drill pipe. The bit was in contact with the seafloor at 3670.7 meters below rig floor (mbrf). The hole was cored to 7.6 mbsf in 75 min (Table 1), at which depth we had to connect more drill pipe. Although the bit was at 4 mbsf when the connection was made, the pipe pulled out of the hole when the ship heaved from a large wave. We recovered the core barrel, but two latch fingers were left in the motor and we had to pull the drill string to assure that its segments were not positioned so as to damage the core barrel and the motor.

### Hole 734B

Because of the relatively favorable drilling conditions in Hole 734A, we decided to try the rotary drilling system in an effort to obtain deeper penetration. The bit took weight at 3681.5 mbrf and was advanced 9.5 m in 10 min (Table 1). A 1.1-m-long core composed of sand and gravel and foraminiferal ooze was recovered. Four more cores were attempted; little or no weight was required, and the drilling time for each core was only 2 to 4 min. No core was recovered. At 41.5 mbsf, we ran a deviation survey in an attempt to determine the angle of the BHA. We suspected that the drill pipe might be going down the side of a cliff, not drilling a hole. The pictures were blurred because of pipe mo-

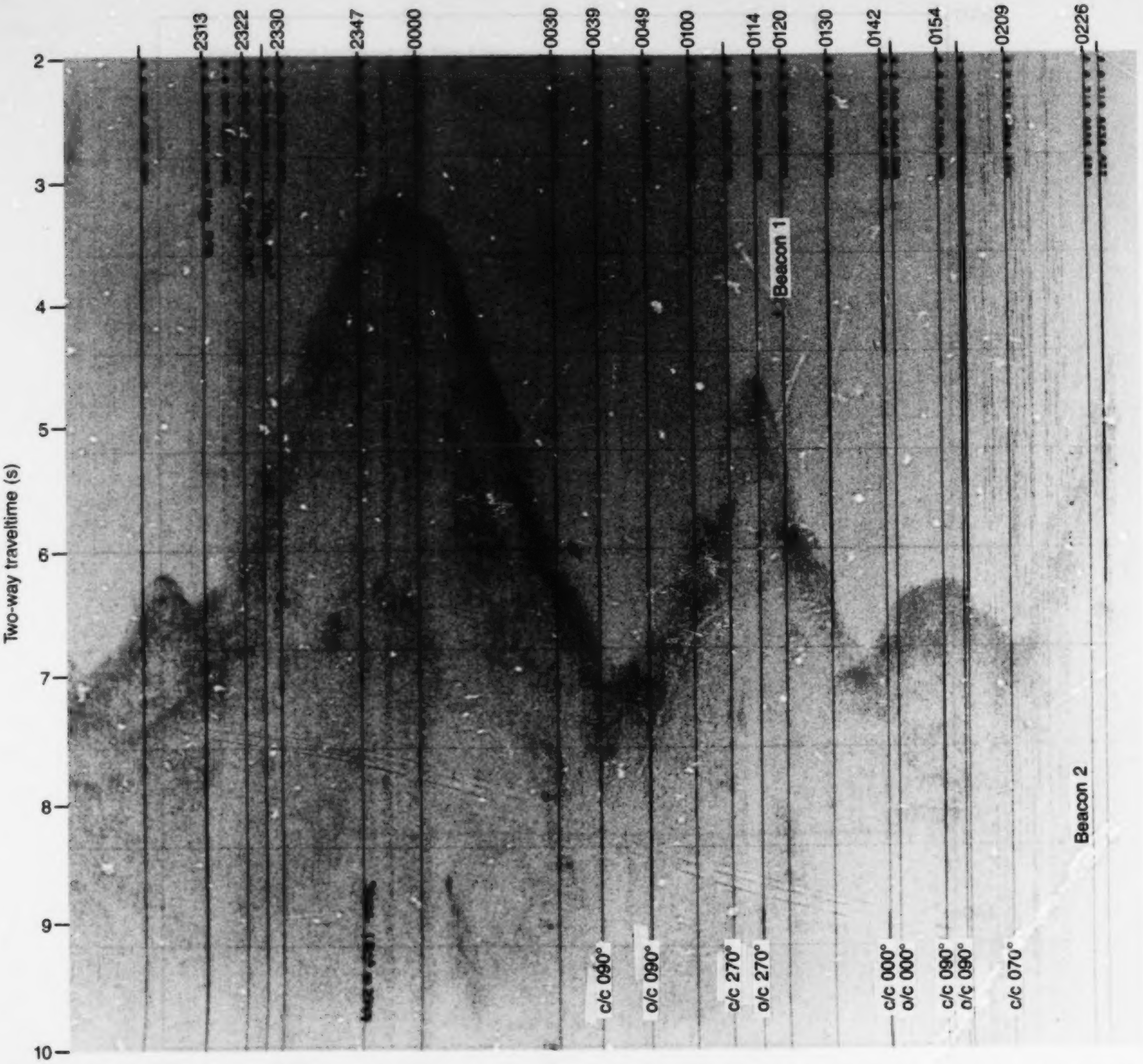

Figure 3. Seismic profile recorded during the approach to Site 734 between about 2240 hr (UTC), 5 November, and 0230 hr (UTC), 6 November 1987. Recording range was 2–10 s, and ship's speed was about 5 to 6 kt. Acoustic beacons were dropped at 0120 and 0226 hr (UTC) on 6 November 1987.

tion, but our suspicions were confirmed when the next core was cut without rotation.

### Hole 734C

We pulled the bit well clear of the seabed, and the ship was repositioned about 50 m northwest (Fig. 5). The bit tagged bottom at 3706 mbrf and was advanced 19 m with 20 pump strikes per minute and 0 rpm. No doubt the bit went down the side of the hill again.

### Hole 734D

The ship was repositioned 50 m north (Fig. 5). The bit tagged bottom at 3720 mbrf and was advanced 19.5 m in 6 min. Once again, the drill was going downslope. A total of 0.79 m of sand and gravel was recovered (Table 1).

### Hole 734E

We decided to conduct another television/sonar survey in an attempt to find a site more suitable for spud-in. The television/sonar was run to the seafloor and an 8-hr survey was conducted. We located a flat area that appeared suitable for spudding northwest of Hole 734D (Fig. 5). The television/sonar was recovered, and the bit took weight at 3746.2 mbrf (Table 1). We rotated the pipe for 90 min, and it advanced 9.5 m. It looked as if we had achieved a successful spud-in using the rotary system. However, at 9.5 mbsf the bit suddenly became stuck. The pipe was worked with up to 200,000 lb overpull for 45 min. The stuck pipe was worked up the hole about 4 m, at which point it came free. Because of stretch, the drill pipe rebounded out of the hole.

The wireline was run to recover the core barrel, but the barrel could not be latched. We then checked the pump rate, but pressure was low, indicating that the BHA was open-ended.

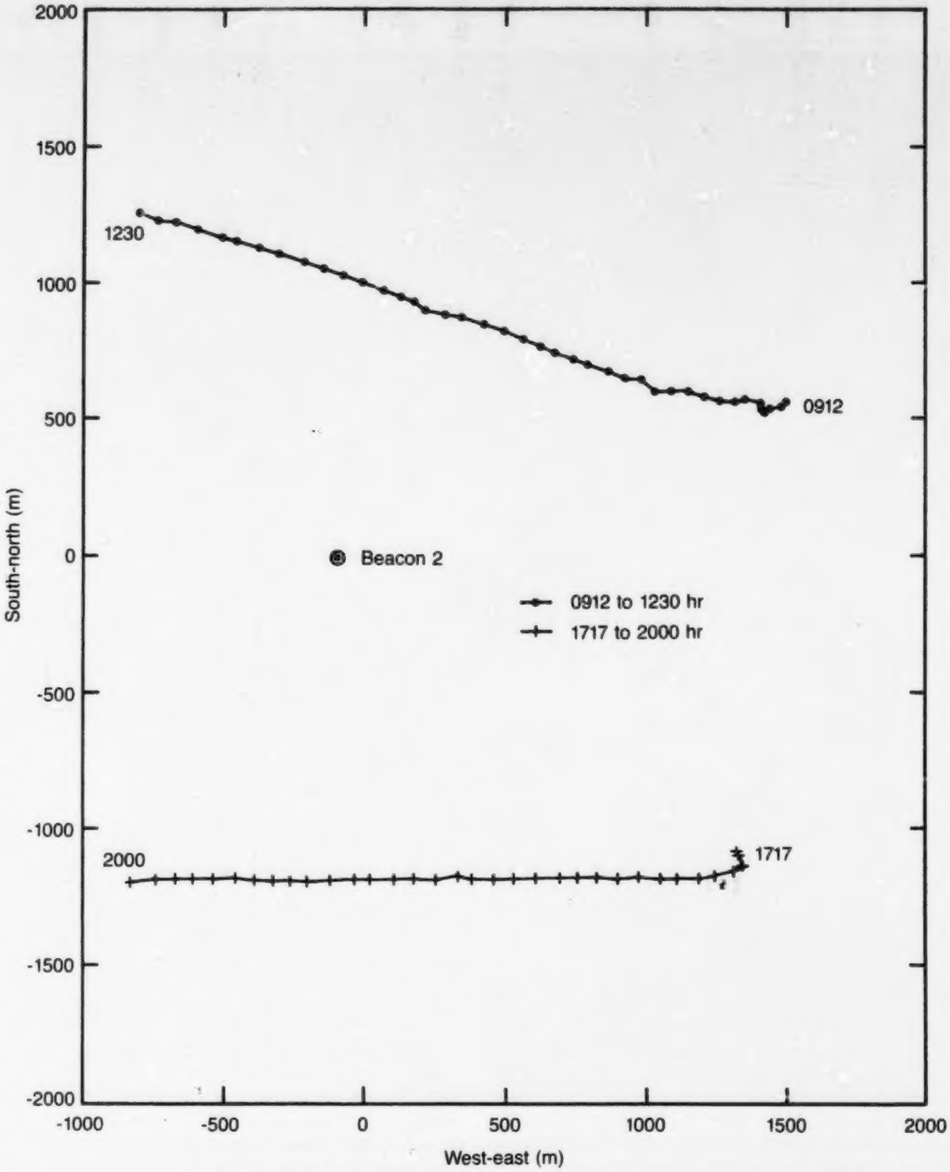

Figure 4. Navigation for two of the three television/sonar survey profiles at Site 734 on 6 November 1987. Symbols along profiles are shown approximately at 5-min intervals during surveys, between times (UTC) as indicated. Coordinates are in meters from beacon 2. The southernmost profile south of beacon 1 is not shown (survey data between 0450 and 0830 hr UTC, 7 November 1987).

We pulled the drill pipe to the surface and found that the bit had been torn from the bottom drill collar. The failure point was the pin of the collar. The fracture surface indicated a tension-bending overload. Note that it should take at least 1 million pounds of tension to pull apart this particular pin. Most amazingly, the drill collar was bent 4 m up from the pin. None of the experienced oilfield personnel onboard the ship had ever seen a bent drill collar.

## Hole 734F

We again ran the television/sonar to the seafloor and found a flat area about 350 m upslope of Holes 734A through 734E. Because of our earlier problems when the bit of the rotary drilling assembly went downhill, the coring motor and a 10 1/2 in. bit were picked up. The BHA was inspected on its way into the hole, and we found a cracked drill-collar pin.

Using the television/sonar, we saw the bit skid around on a hard flat bottom, but after a few minutes we were able to begin drilling at 3436 mbrf. A few tenths of a meter of hole had been drilled before our view was obscured by a cloud of cuttings in the water. The television/sonar was raised several meters to remove it from the worst of the drill-pipe vibration. Surface indications were that we were drilling a new hole in a soft formation; a total of 14 m of hole was drilled in 14 min. The cloud of

Table 1. Coring summary for Site 734.

| Hole, Core no. | Date (Nov. 1987) | Time (local) | Total depth[a] (mbrf) | Depth (mbsf) | Length advanced (m) | Length cored (m) | Length recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| 118-734A-1D | 8 | 1630 | 3670.7-3678.3 | 0-7.6 | 7.6 | 7.6 | 0.05 | 0.7 |
| 734B-1R | 9 | 1250 | 3681.5-3691.0 | 0.0-9.5 | 9.5 | 9.5 | 1.10 | 11.6 |
| 734B-2R | 9 | 1345 | 3691.0-3700.5 | 9.5-19.0 | 9.5 | 9.5 | 0.0 | 0 |
| 734B-3R | 9 | 1450 | 3700.5-3710.0 | 19.0-28.5 | 9.5 | 9.5 | 0.0 | 0 |
| 734B-4R | 9 | 1555 | 3710.0-3719.5 | 28.5-38.0 | 9.5 | 9.5 | 0.0 | 0 |
| 734B-5R | 9 | 1640 | 3719.5-3729.0 | 38.0-47.5 | 9.5 | 9.5 | 0.0 | 0 |
| [b]734C-1R | 9 |  | 3706.0-3725.0 | 0-19.0 | 19.0 | 19.0 | 0 | 0 |
| 734D-1R | 9 | 2300 | 3720.0-3739.5 | 0-19.5 | 19.5 | 19.5 | 0.79 | 4.0 |
| [c]734E-1R | 9 |  | 3746.2-3755.7 | 0-9.5 | 9.5 | 9.5 | 0 | 0 |
| 734F-1D | 12 | 0145 | 3436.0-3450.0 | 0-14.0 | 14.0 | 14.0 | 0.10 | 0.7 |
| 734G-1D | 12 | 1240 | 3428.5-3441.5 | 0-13.0 | 13.0 | 13.0 | 0 | 0 |
| 734G-2D | 12 | 1730 | 3441.5-3451.0 | 13.0-22.5 | 9.5 | 9.5 | 0 | 0 |
| [d]734G-3D | 13 | 1700 | 3451.0-3459.5 | 22.5-31.0 | 8.5 | 8.5 | 5.95 | 70.0 |

[a] Determined from pipe length below rig floor.
[b] Core barrel not retrieved.
[c] No core—lost BHA.
[d] Drill cuttings.

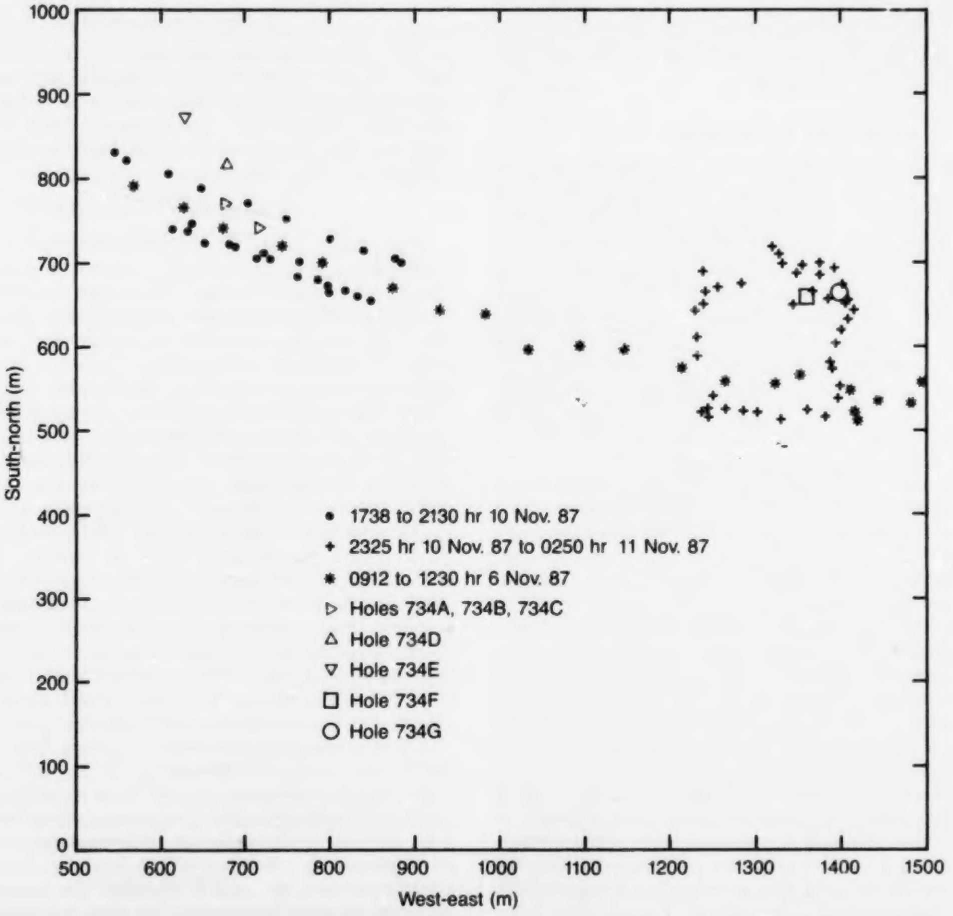

Figure 5. Navigation for television/sonar minisurveys at Site 734. Coordinates are in meters from beacon 2. Star symbols are part of northernmost survey line shown in Figure 4. Solid dots and plus symbols indicate locations along minisurvey tracks at approximate 5-min intervals, between times (UTC) as indicated. Open symbols are hole locations at this site.

cuttings was allowed to settle, and the television/sonar was lowered to observe the new hole. The bit had become unseated from the hole and once again had gone down a steep slope.

### Hole 734G

The bit was raised to 3423 mbrf, and the ship repositioned a few meters east as we searched for a better drill site (Fig. 5). A likely spot was found, and Hole 734G was begun at 3428.5 mbrf (Table 1). The first core penetrated 13 mbsf, but there were serious problems with the hole collapsing when the bit was raised up off the bottom. Before attempting to wireline the core barrel, we filled the hole with 10.2 lb/gal ultra high-viscosity mud. Core recovery was zero. The second core advanced 9.5 m in 3.4 hr. Although more than 100 bbl of mud was used in slugs, the hole kept collapsing. Thus, while the barrel was wirelined, 8 m of hole was lost; again, nothing was recovered.

The third core advanced the bit 8.5 m in 7 hr to 31 mbsf (Table 1). Torque and drag were not abnormal, but nearly every time the bit was raised from bottom, the hole filled in beneath it. There were no incidents of the hole filling in from above, it was always from beneath the bit. We also saw that when the pumps were working, the caving problem was less serious. At 31 mbsf, we attempted to wireline the core barrel. The barrel was not latched during three runs; eventually, the collapsing hole drove the bit up to the mudline and the hole had to be abandoned. We recovered 5.95 m of drill cuttings and breccia, with some calcareous/foraminiferal ooze.

## SEDIMENTOLOGY

Approximately 8 m of sediment was recovered in three of seven holes drilled at Site 734. In Hole 734B, coring from 0 to 9.5 mbsf recovered a single graded section 76 cm long (Section 118-734B-1R-1). Recovery from the core-catcher sample was a 35-cm-thick interval of pebble-sized material. Sediment at the base of Section 118-734B-1R-1 is well-sorted, dark to very dark grayish brown (2.5Y 4/2) gravel of igneous lithology: serpentinite, amphibolite, metagabbro, metabasalt, and 10%-15% alteration minerals (aragonite, prehnite, talc, and tremolite). Fragments range up to 3.5 cm long and are angular to subangular. Grain size decreases smoothly upward to a well-sorted coarse sand at a depth of about 50 cm, with no apparent change in lithology. There is no visual evidence of stratification within the graded interval. Most sand and gravel grains are angular. Many are platy, but there is no apparent preferred orientation. At a depth of 25 cm, foraminifers appear and increase in abundance upward to 30%-40% at a depth of about 5 cm; grain size decreases to medium sand. At a depth of 4 cm, there is a gradual color and compositional change over a 2- to 3-mm-thick interval. This contact curves down about 10 cm along the core liner, and a sediment gap of 2-3 cm occurs in the middle of the core. Above the contact, the sediment is homogeneous, light gray (2.5Y 7/2), well-sorted, foraminiferal ooze (fine sand). At a depth of 1 cm, there is a sharp contact overlain by homogeneous, light brownish-gray (2.5Y 6/2) foraminiferal ooze. The foraminifers are distinctly smaller above the contact.

In Hole 734D, we recovered a graded section 79 cm thick (Section 118-734D-1R-1) having texture and lithology similar to those at Hole 734B. Grain size decreases upward, with no stratification from gravel at the base to fine foraminiferal sand at the top. The principal lithology of the gravel pebbles is amphibolite mylonite. Carbonate veins (comb-textured aragonite) and coatings are common. Concretions, formed of silt and sand-sized igneous rock chips (commonly serpentinite) cemented by aragonite, make up 10%-20% of the gravel.

The material recovered in Hole 734D differs from that in Hole 734B in two respects. First, the core from Hole 734D has a large clast (about 6 cm in diameter) of foliated serpentinized peridotite resting in a matrix of unconsolidated sand at a depth of between 15 and 20 cm. Second, although foraminifers make up 70%-90% of the sediment in the upper 5 cm, there are no distinct layers of foraminiferal ooze. The size grading, angularity of the grains, and apparent lack of stratification and fabric in sediment recovered in Holes 734B and 734D are consistent with deposition from turbidity currents. However, the weight-on-bit record indicates that during drilling, the bit may have lifted off the bottom of the hole several times. The graded beds may have been sorted by repeated resuspensions and resettling of unconsolidated sediment within the core barrel, by physical movement of the core barrel, and by injection of fluid upward through the bit.

The longest section was obtained from Hole 734G. Although we drilled and cored to 22.5 mbsf in this hole, we recovered no material (Table 1), but after drilling to 31 mbsf, a 6-m-long section (118-734G-3D-1) of soupy sand and gravel having ultramafic lithology, as well as about 20 cm of sticky foraminiferal ooze, were recovered. Based on the soupy nature of the core on recovery, lack of stratification, and the poorly sorted texture, we believe that this sequence probably represents cavings from shallower sediment sections (sticky foraminiferal ooze) and from drill cuttings (rock fragments).

## BIOSTRATIGRAPHY

The sediments recovered from Cores 118-734B-1R, 118-734D-1R, and 118-734G-3D were examined in smear slides and proved to contain abundant and well-preserved foraminifers and calcareous nannofossils. The sediments from Holes 734B and 734D are dated by calcareous nannofossils as Holocene, whereas lower Pleistocene sediments were obtained from Hole 734G.

### Calcareous Nannofossils

From Hole 734B, we examined three levels: Samples 118-734B-1R-1, 1 cm; 118-734B-1R-1, 5 cm; and 118-734B-1R-1, 15 cm, in the light microscope, and Sample 118-734B-1R-1, 5 cm, in the scanning electron microscope as well. Sample 118-734D-1R, 3 cm, also was examined in the light microscope. The nannoflora is composed of dominant *Emiliania huxleyi*, *Gephyrocapsa oceanica*, and *Calcidiscus leptoporus*. Also observed were *Ceratolithus telesmus*, *Ceratolithus cristatus*, *Gephyrocapsa* spp., *Helicosphaera carteri*, *Oolithotus fragilis*, *Pontosphaera indooceanica*, *Pontosphaera japonica*, *Rhabdosphaera claviger*, small placoliths, *Scapholithus fossilis*, *Syracosphaera pulchra*, *Umbellosphaera irregularis*, and *Umbilicosphaera sibogae*.

These sediments belong to Zone NN21 of Martini (1971) and the *Emiliania huxleyi* Acme Zone of Gartner (1977). McIntyre et al. (1970) pointed out that the absence of *Coccolithus pelagicus* in the Southern Hemisphere is a post-glacial phenomenon. Gard (in press) observed that *C. pelagicus* is abundant in the southern Indian Ocean during the last glaciation (oxygen isotope stages 2-4), but is absent in Holocene sediments. As this species was not observed in Holes 734B and 734D, we concluded that these sediments are Holocene.

Three levels were analyzed from Hole 734G: Samples 118-734G-3D-1, 1 cm; 118-734G-3D-1, 10 cm; and 118-734G-3D-2, 1 cm. These samples contain the same nannofossil assemblage, which is dominated by *Gephyrocapsa caribbeanica*. Also present is *C. leptoporus*, *C. pelagicus*, *Helicosphaera sellii*, *H. carteri*, *Pontosphaera* sp., *Pseudoemiliania lacunosa*, *Syracosphaera* sp., *Umbilicosphaera* sp., and *R. claviger*. The presence of *P. lacunosa* and *H. sellii*, in combination with the absence of discoasters, suggests that these sediments are lower Pleistocene and belong to Zone NN19 of Martini (1971). Backman and Shackleton (1983) found that the last discoaster became extinct at 1.88 Ma and that *H. sellii* disappears at about 1.37 Ma, which thus gives maximum and minimum ages for the sediments from Hole 734G.

## LITHOSTRATIGRAPHY

No coherent section was recovered from any of the holes at Site 734. From Core 118-734A-1D we recovered one serpentinized peridotite cobble, and from Core 118-734F-1D we recovered five angular serpentinite pebbles. Cores 118-734B-1R, 118-734D-1R, and 118-734G-3D all contained various amounts of drilling-disturbed sediments and drill cuttings. These cuttings are graded in each core from pebbles to coarse sand to fine sand. The upper intervals in each core also include foraminifers. There is a serpentinite cobble between 13 and 20 cm in Section 118-734D-1R-1. Clasts in these cuttings include serpentinite, metagabbro, calcite-cemented breccias, and metabasalt. Serpentinite and calcite-cemented breccias and veins appear to be the dominant constituent of the pebbles and sand.

## PETROGRAPHY

### Introduction

Approximately 8 m of rock and sediment was recovered from Holes 734A through 734G, with a maximum penetration depth of 47.5 m in Hole 734B. All material recovered was moderately to highly metamorphosed, altered and/or deformed, and includes predominantly serpentinized peridotite and metagabbro. In this section, the primary mineralogy was interpreted from petrographic descriptions of selected clasts. Detailed discussions of alteration, metamorphism, and deformation are given in the "Metamorphism, Deformation, and Alteration" section (this chapter). Recovered material ranges from silt to pebble-sized (<6 cm) angular clasts. In three cores (118-734B-1R, 118-734D-1R, and 118-734G-3D), the material increases in grain size from top to bottom of the core. Thin sections were prepared from selected rubble clasts and are described next.

### Serpentinized Peridotites

Ultramafic rocks recovered at Site 734 consist predominantly of foliated porphyroclastic serpentinized lherzolite and harzburgite. Two of the samples, 118-734B-1R, CC, 8-10 cm, Piece 3 and 118-734D-1R-1, 18-24 cm, Piece 1, are crosscut by aragonite veins. Point-counting of two samples, 118-734A-1D-1, 0-5 cm, Piece 1, and 118-734D-1R-1, 18-24 cm, Piece 1, indicates that these rocks contain 71%-77% serpentine (lizardite), 10%-11% magnetite, and less than 10%-15% relict primary olivine, orthopyroxene, and clinopyroxene. Of the relict minerals, olivine is most abundant (5%-10%) and occurs as small crystals (0.1-0.2 mm in size) or granulated masses interspersed within the mesh-textured serpentine. Orthopyroxene is largely replaced by bastite, with relict orthopyroxene making up less than 3% of most samples. However, bastite pseudomorphs suggest that orthopyroxene may have composed 10%-20% of the primary mineral assemblage. Relict clinopyroxene generally constitutes 1%-5% of the rock and occurs as small clusters of equant crystals 0.5 to 2 mm in size, although a few crystals as large as 4 mm were observed in Sample 118-734B-1R, CC, 8-10 cm, Piece 3. Golden brown, holly-leaf chromium-spinel occurs in abundances of less than 1%, but is largely unaltered. In Sample 118-734D-1R-1, 18-24 cm, Piece 1, spinel was observed in symplectic intergrowth with clinopyroxene. The present abundance of clinopyroxene (<5%) in these samples suggests that they were originally clinopyroxene-poor lherzolites or harzburgites.

### Mafic Rocks

Gabbroic rocks recovered from Site 734 (Samples 118-734D-1R-1, 59-61 cm, Piece 1, and 118-734B-1R, CC, 5-7 cm, Piece 2) are plagioclase plus clinopyroxene rocks containing less than 40% of the primary mineralogy presented. Original proportions of plagioclase and clinopyroxene are estimated at 70%-85% and 15%-30%, respectively. Sample 118-734B-1R, CC (5-7 cm, Piece 2) is richer in plagioclase and was interpreted as an orthocumulate. In the gabbroic rocks, plagioclase is replaced by clay minerals, albite, actinolite, and prehnite, whereas clinopyroxene is replaced by amphibole. No relict iron-titanium oxides are present.

The remaining mafic rocks recovered include two samples of amphibolite mylonite (Samples 118-734D-1R-1, 74-77 cm, Piece 1, and 118-734D-1R-1, 67-68 cm, Piece 1) and one carbonate-cemented breccia that contains amphibolite and serpentinite clasts (Sample 118-734B-1R, CC, 0-4 cm, Piece 1). Two of these samples, 118-734B-1R, CC, 0-4 cm, Piece 1, and 118-734D-1R-1, 67-68 cm, Piece 1, are devoid of primary minerals, and Sample 118-734D-1R-1, 74-77 cm, Piece 1, has only about 2% primary subhedral plagioclase, with possible magmatic twinning. Sample 118-834D-1R-1, 67-68 cm, Piece 1, is fine-grained and was probably metamorphosed from a basalt, whereas the coarse grain size of porphyroclasts in Sample 118-734D-1R-1, 74-77 cm, Piece 1, suggests a gabbroic protolith.

## METAMORPHISM, DEFORMATION, AND ALTERATION

### Introduction

Coring at Site 734 recovered pebbles from unconsolidated rubble. The pebbles included: serpentinized peridotite, metamorphosed basalt and gabbro, foliated amphibolite with protolith unclear, a crosscutting network of calcium silicate and carbonate veins, and a carbonate-cemented breccia containing clasts of both foliated amphibolite and serpentinized peridotite, cut by veins of aragonite. Here, we describe the metamorphism, deformation, and alteration of the lithic fragments and summarize the mineralogy of the calcium silicate veins. This description is based on thin sections from selected pebbles: Samples 118-734A-1D-1, 0-5 cm, Piece 1; 118-734B-1R, CC, 8-10 cm, Piece 3; and 118-734D-1R-1, 18-24 cm, Piece 1; for the serpentinized peridotites; Samples 118-734B-1R, CC, 5-7 cm, Piece 2, and 118-734D-1R-1, 59-61 cm, Piece 1 for the metagabbro; Sample 118-734D-1R-1, 74-77 cm, Piece 1 for the metabasalt; Sample 118-734D-1R-1, 67-68 cm, Piece 1, for a foliated amphibolite; and Sample 118-734B-1R, CC, 0-4 cm, Piece 1, for the carbonate-cemented breccia.

### Serpentinized Peridotites

The serpentinized peridotites consist of tectonized harzburgite and lherzolite (see "Petrography" section, this chapter), about 70% serpentinized. The serpentinization was static and preferentially affected the olivine-rich parts of the samples, now almost entirely replaced by a mesh of serpentine containing disseminated magnetite grains and brown clay minerals. Fresh pyroxene and spinel are still abundant. Extension fractures 1-mm-wide are filled with serpentine. In two of the three samples studied (118-734B-1R, CC, 8-10 cm, Piece 3, and 118-734D-1R-1, 18-24 cm, Piece 1), these extension fractures are nearly perpendicular to the spinel foliation and lineation. In all three of the samples studied, the serpentine mesh and extension veins are crosscut by 1-mm-wide, undeformed, carbonate veins.

The peridotites have a primary porphyroclastic texture, with a foliation and lineation defined by the elongation of spinel and pyroxene grains. The olivine grains (less than 1 mm in size) have straight grain boundaries and display deformation subgrain boundaries. Orthopyroxene and clinopyroxene grains are kinked and locally recrystallized to very small grains (less than 0.05 mm). These textures of the primary peridotites (see "Petrography" section, this chapter) suggest that the samples were plastically deformed at high temperatures (probably mantle temperatures) and moderate to relatively high differential stresses.

## Metamorphosed Mafic Rocks

Two metagabbros (Samples 118-734B-1R, CC, 5–7 cm, Piece 2, and 118-734D-1R-1, 59–61 cm, Piece 1), one metabasalt (Sample 118-734D-1R-1, 74–77, Piece 1), an amphibolite mylonite (Sample 118-734D-1R-1, 67–68 cm, Piece 1) and clasts of foliated amphibolite in the carbonate-cemented breccia (Sample 118-734B-1R, CC, 0–4 cm, Piece 1) were examined petrographically. The extent of plastic deformation varies, being greater in the foliated amphibolite and in the metabasalt and comparatively less in metagabbro Sample 118-734D-1R-1, 59–61 cm, Piece 1. The only undeformed sample (118-734B-1R, CC [5–7 cm, Piece 2]) is a metagabbro.

All samples examined show evidence of an early high-temperature metamorphism that includes replacement of clinopyroxene by green or pale brown amphibole and recrystallization of the igneous plagioclase in the metagabbros. The clasts of foliated amphibolite in the carbonate breccia are similarly composed of aligned crystals of pale brown amphibole and metamorphic plagioclase. In the amphibolite mylonite, the amphiboles exhibit deformation twins, and the plagioclase and amphibole are somewhat segregated into layers. In all deformed samples, the formation of amphibole and recrystallization of plagioclase appear to be syndeformational. In the metagabbro (Sample 118-734D-1R-1, 59–61 cm, Piece 1), large grains of an unusually deep yellow sphene intermix with recrystallized amphibole that forms a metamorphic halo around a clinopyroxene porphyroclast. Gray sphene is found as small grains in this halo, and inclusions in the amphibolitized rim of the original pyroxene.

## Static Alteration and the Calcium Silicate Veins

Early high-temperature deformation and metamorphism were followed by static metasomatic (?) or hydrothermal alteration at moderate temperatures. This alteration includes the following:

1. Replacement of plagioclase by prehnite and/or albite mixed with brown clay minerals.
2. Replacement of serpentine by tremolite and talc in the clasts of serpentinized peridotite of the carbonate breccia. The talc and tremolite mimics the mesh texture of the serpentine; euhedral magnetite grains contained within the serpentinite were replaced by hematite.
3. Limited replacement of primary hornblende by actinolite.

These replacements are all related to the network of fractures and calc-silicate veins that crosscuts most samples from Site 734. Prehnite is the most abundant vein-forming mineral in the metagabbro. The intergrown talc and tremolite fill veins in the breccia, as well as replace earlier minerals. A yellowish carbonate fills veins in the deformed metagabbro. A very tiny vein of chlorite crosscuts the mylonite. Other calcium silicates may be present in trace amounts. The vein network is best developed in the carbonate breccia (Sample 118-734B-1R, CC [0–4 cm, Piece 1]). An X-ray diffractogram revealed that all the multiple carbonate veins are aragonite. This mineral occurs as coarse twinned crystals and "stalactites" perpendicular to, and penetrating into, the fractures to form a comb texture. These vein fragments having comb textures are common in the rubble and may also make up the veins in the serpentinites.

## GEOCHEMISTRY

Five fragments from the coarse gravels recovered at Site 734 were analyzed for major and trace elements using the shipboard X-ray fluorescence system. The analytical procedure is described in the "Introduction and Explanatory Notes" (this volume). Results are listed in Table 2.

**Table 2. Compositions of major and trace elements of Site 734 samples.**

| Hole: | 734B* | 734B** | 734D | 734D | 734D | 734G |
|---|---|---|---|---|---|---|
| Section: | 1R-1 | 1R-1 | 1R-1 | 1R-1 | 1R-1 | 3D-3 |
| Interval (cm): | 68–69 | 68–69 | 59–61 | 66–67 | 74–77 | 47–51 |
| Type | SE | | MG | SE | MB | SE |
| (in wt%) | | | | | | |
| $SiO_2$ | 35.15 | 46.7 | 49.28 | 46.21 | 45.03 | 45.04 |
| $TiO_2$ | 0.03 | 0.04 | 4.16 | 0.06 | 2.89 | 0.78 |
| $Al_2O_3$ | 2.04 | 2.7 | 15.21 | 1.54 | 15.46 | 4.12 |
| $Fe_2O_3$ | 6.09 | 8.1 | 11.01 | 10.72 | 9.82 | 10.61 |
| MnO | 0.09 | 0.12 | 0.25 | 0.30 | 0.19 | 0.15 |
| MgO | 30.92 | 41.0 | 6.77 | 40.31 | 13.50 | 31.98 |
| CaO | 23.67 | 0.6 | 6.93 | 0.63 | 9.68 | 5.99 |
| $Na_2O$ | 0 | 0 | 5.64 | 0 | 3.46 | 0.61 |
| $K_2O$ | 0 | 0 | 0.45 | 0.07 | 0.09 | 0.08 |
| $P_2O_5$ | 0.01 | 0.01 | 0.62 | 0.04 | 0.41 | 0.13 |
| $Cr_2O_3$ | 0.37 | 0.5 | — | 0.18 | — | 0.24 |
| NiO | 0.22 | 0.3 | — | 0.29 | — | 0.19 |
| SrO | 0.50 | — | — | | — | |
| Sum | 99.09 | 100.00 | 100.32 | 100.35 | 100.32 | 99.92 |
| LOI | 23.2 | | 2.81 | 13 | 3.62 | 11.9 |
| (in ppm) | | | | | | |
| V | 59 | | 359 | 89 | 308 | 92 |
| Cr | 2510 | | 33 | 1233 | 217 | 1607 |
| Ni | 1705 | | 177 | 2260 | 307 | 1553 |
| Cu | 61 | | 105 | 95 | 31 | 32 |
| Zn | 50 | | 47 | 160 | 47 | 86 |
| Rb | — | | 4 | 1 | 2 | 1 |
| Sr | 4211 | | 192 | 25 | 122 | 397 |
| Y | 1.2 | | 76 | 2.4 | 73 | 18 |
| Zr | 20 | | 388 | 9.7 | 304 | 34 |
| Nb | 0.8 | | 10 | 1 | 9 | 2.8 |

* Mixture of serpentine and aragonite vein material.

** Approximate composition of silicate fraction.

Major and trace elements on anhydrous basis; Sum is as measured by XRF on ignited samples; Type is SE = serpentinite; MG = porphyroclastic metagabbro; MB = foliated metabasalt; LOI = loss on ignition.

Sample 118-734D-1R-1, 59–61 cm, Piece 1, is a medium- to coarse-grained porphyroclastic metagabbro in which primary plagioclase is almost completely replaced by clay minerals and albite. The high titanium and iron contents and the uniformly high abundances of the strongly to moderately incompatible trace elements vanadium, yttrium, zirconium, and niobium set this metagabbro apart from the mesocumulate gabbros of Site 733 ("Geochemistry" section, Site 733 chapter). Because the zirconium/niobium (38.8), zirconium/yttrium (5.1), and yttrium/niobium (7.6) ratios are indistinguishable from primary magmatic ratios of depleted-normal mid-ocean ridge basalts (see "Geochemistry" section, Site 732 chapter), we believe it improbable that the enrichment of iron, titanium, vanadium, yttrium, zirconium, and niobium is from secondary alteration. Thus, the chemical composition of this rock corresponds to an iron- and titanium-enriched magmatic liquid, probably a recrystallized, altered basaltic dike (diabase) rather than a cumulate gabbro.

Sample 118-734D-1R-1, 74–77 cm, Piece 1, is a fine-grained foliated granoblastic metabasalt. It is less enriched in iron and titanium than Sample 118-734D-1R-1, 59–61 cm, Piece 1, but shows a similar enrichment of the incompatible trace elements vanadium, yttrium, zirconium, and niobium. Zirconium/niobium, zirconium/yttrium, and yttrium/niobium ratios are nearly the same in both samples. The relatively high MgO, chromium, and nickel contents of the metabasalt may be an artifact of sampling and reflect admixture of ultramafic fragments in the sample taken for analysis.

The other three samples analyzed are serpentinized peridotite. Judging from the high CaO content and high loss on ignition (loss of $CO_2$ in addition to $H_2O$), calcium carbonate vein material makes up about 30% of Sample 118-734B-1R-1, 68-69 cm. As is usually the case for serpentinized oceanic ultramafic rocks (e.g., Bonatti and Hamlyn, 1981), the calcium carbonate is fibrous aragonite (see "Metamorphism, Deformation, and Alteration" section, this chapter). The presence of aragonite explains the extremely high strontium content of this sample (8000-10,000 ppm strontium in marine aragonite vs. 1500-2500 ppm strontium in marine calcite).

Sample 118-734G-3D-3, 47-51 cm, consists of sand-sized (1 to 5 mm), lithic rubble and apparently is a mixture of serpentinite, aragonite (see high strontium content) and gabbro/metabasalt (see higher titanium, aluminum, yttrium, and niobium contents).

Sample 118-734D-1R-1, 66-67 cm, consists of a few serpentinized fragments, 1-2 cm in size, containing only minor amounts of carbonate vein material. This sample is probably the most representative of the ultramafic rocks that crop out at Site 734. The rather low titanium, aluminum, and calcium contents suggest that the serpentinites were derived from fairly depleted precursors of harzburgite.

## SUMMARY AND CONCLUSIONS

Site 734 is located on the east wall of the Atlantis II Transform at about 32°07′S and 57°08′E. The objectives at this site were (1) to sample a section of upper mantle peridotite and (2) to drill a deep basement hole that could be used to conduct downhole geophysical measurements and experiments. From two dredge hauls in this vicinity, performed during the precruise site survey, mostly peridotite and dunite, with minor basalt, were recovered. Site 734 was selected for basement drilling because the topography indicated a steep, regular slope for this part of the wall with no indication of slumping or landsliding. One structural model for the transform wall suggested formation along a series of steep, normal faults separated by relatively flat benches (H. Dick, pers. comm., 1987). The presence of steep slopes on this part of the transform wall suggested that it might be a good location for finding basement outcrops. We planned to find a bench on which the hard-rock guidebase might be deployed and to drill into the underlying peridotite.

Two areas of basement outcrop were located during a television/sonar survey of the area: one on the wall of a gully or small canyon at a water depth of about 3750 m and the other on a small fault scarp, about 700 m to the east and 350 m shallower. Seven holes were drilled at this site: Holes 734A through 734E at the deeper site and Holes 734F and 734G at the shallower site. Significant penetration was achieved only in Holes 734B and 734G (47.5 mbsf and 31.0 mbsf, respectively). A total of about 8 m of sediment containing various clasts of igneous and metamorphic rock was recovered, chiefly from Holes 734B, 734D, and 734G.

Similar sequences of graded sand and gravel, each about 80 cm long, were recovered in Holes 734B and 734D. The grain size in these sequences decreases regularly upward from pebbles at the base to fine sand at the top. The upper few centimeters in each sequence consist of foraminiferal ooze and sand. Rock fragments in the gravels range up to 3.5 cm long and are angular to subangular. They consist of serpentinite, amphibolite mylonite, metagabbro, and metabasalt. Fragments of aragonite and other alteration minerals, such as prehnite, talc, and tremolite, make up 10%-15%.

A 6-m-long section of highly disturbed, soupy sand and gravel composed of ultramafic material was recovered in Hole 734G. Based on its soupy nature, lack of stratification, and poorly sorted texture, we believe that this material represents drill cuttings or sediment that slumped into the hole from above.

The uppermost sediments in Holes 734B and 734D contain abundant and well-preserved foraminifers and calcareous nannofossils. The nannofossils were assigned to Zone NN21 of Martini (1971) and are dated as Holocene based on the absence of *Coccolithus pelagicus*. The sediments recovered from Hole 734G contain a nannofossil assemblage dominated by *Gephyrocapsa caribbeanica* and were assigned to Zone NN19 of Martini (1971). Based on the absence of discoasters, the sediments are probably lower Pleistocene, between 1.37 and 1.88 Ma.

Most of the recovered clasts in the sediment consist of highly metamorphosed and deformed peridotite and metagabbro; a few clasts are composed of amphibolite mylonite, metabasalt, and carbonate-cemented breccia that contain amphibolite and serpentinite. The ultramafic rocks are foliated lherzolite and harzburgite composed of about 75% serpentine, 10% magnetite, and 10%-15% relict primary olivine, orthopyroxene, and clinopyroxene. Two of the ultramafic samples are cut by calc-silicate veins composed chiefly of prehnite. In the metagabbros the original plagioclase and clinopyroxene have been largely replaced by clay minerals, albite, actinolite, and prehnite. Both the mylonite and breccia are almost devoid of primary minerals.

The television/sonar survey conducted at this site revealed a steep slope (about 24°) heavily mantled with talus and sediment. Basement crops out only along steep cliffs on the walls of gullies and canyons or on fault scarps. None of the recovered core can be unequivocally interpreted as basement, but the abundance of ultramafic clasts and fragments suggests that such material is present beneath the rubble and talus.

Site 734 was abandoned after we made numerous unsuccessful attempts to sample basement. We encountered considerable difficulty in starting a hole on such a steeply sloping cliff. For those holes where spud-in was successful (Holes 734B and 734G), drilling conditions were poor, and we decided that the site was unsuitable for deployment of the hard-rock guidebase.

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**Ms 118A-106**

# 6. SITE 735[1]

## Shipboard Scientific Party[2]

### HOLE 735A

**Date occupied:** 14 November 1987

**Date departed:** 15 November 1987

**Time on hole:** 30 hr 15 min

**Position:** 32°43.315'S, 57°15.864'E

**Bottom felt (rig floor, m; drill pipe mesurement):** 738.0

**Distance between rig floor and sea level (m):** 11.1

**Water depth (drill pipe measurement from sea level, m):** 726.9

**Total depth (rig floor, m):** 745.0

**Penetration (m):** 7.0

**Number of cores (including cores with no recovery):** 1

**Total length of cored section (m):** 7.0

**Total core recovered (m):** 0.10

**Core recovery (%):** 1.4

**Basement:**
Depth (mbsf): 0
Nature: metagabbro

### HOLE 735B

**Date occupied:** 15 November 1987

**Date departed:** 11 December 1987

**Time on hole:** 25 days 22 hr 45 min

**Position:** 32°43.395'S, 57°15.959'E

**Bottom felt (rig floor, m; drill pipe measurement):** 731.0

**Distance between rig floor and sea level (m):** 11.1

**Water depth (drill pipe measurement from sea level, m):** 719.9

**Total depth (rig floor, m):** 1231.7

**Penetration (m):** 500.7

**Number of cores (including cores with no recovery):** 88

**Total length of cored section (m):** 500.7

**Total core recovered (m):** 434.81

**Core recovery (%):** 86.8

**Basement:**
Depth (mbsf): 0
Nature: gabbro, metagabbro, mylonite, troctolite, trondhjemite
Measured velocity (km/s): 7.1

### HOLE 735C

**Date occupied:** 4 December 1987

**Date departed:** 5 December 1987

**Time on hole:** 5 hr 15 min

**Position:** 32°43.40'S, 57°15.45'E

**Bottom felt (rig floor, m; drill pipe measurement):** 753.9

**Distance between rig floor and sea level (m):** 11.1

**Water depth (drill pipe measurement from sea level, m):** 742.8

**Total depth (rig floor, m):** 753.9

**Penetration (m):** 0

**Number of cores (including cores with no recovery):** 0

**Total length of cored section (m):** 0

**Total core recovered (m):** 0

**Core recovery (%):** 0

**Principal results:** Site 735 is located on a shallow platform in about 700 m of water on the east rim of the Atlantis II Transform. This platform, about 9 km long in a north-south direction and 4 km wide, is one of a series of uplifted blocks that are connected by saddles to form a long, linear ridge parallel to the Atlantis II Transform.

The platform at Site 735 has a flat surface, which suggests that it is a wave-cut feature. Its position in the magnetic anomaly pattern on the east transform wall suggests a crustal age of about 12 Ma. A television/sonar survey of the seafloor revealed basement outcrops locally mantled with thin sediment. Many of the outcrops have a well-developed, steeply dipping foliation and are cut by a regular pattern of faults or joints.

From an unsupported test spud-in and using the coring motor, we recovered 0.1 m of gabbro from Hole 735A. We then deployed the hard-rock guidebase, and drilling commenced in Hole 735B. The coring motor was used to start the hole and to drill to a depth of 60 meters below seafloor (mbsf). A standard rotary coring system then was used to drill to 500 mbsf. The newly developed navidrill was used to cut an additional 0.7 m. The entire 500.7-m-deep hole was drilled in 17 days, resulting in an average rate of penetration of 30 m/day.

A total of 435 m of olivine gabbro, olivine-bearing gabbro, two-pyroxene gabbro, iron-titanium oxide gabbro, troctolite, and micro-gabbro with rare basalt and trondjhemite was recovered from Hole 735B for an average recovery of 87%. These rocks have undergone varying degrees of plastic and brittle deformation, and many have well-developed foliations. Six major lithologic units were recognized in the sequence, based primarily on igneous mineralogy, mineral compositions, and degree and style of deformation.

Lithologic Unit I is a 39.5-m-thick sequence of foliated metagabbro having porphyroclastic to mylonitic textures. Rock types include poorly foliated metagabbro, porphyroclastic metagabbro, mylonite, gneissic metagabbro, and augen gneissic metagabbro. Igneous textures have been completely destroyed, and the rocks now consist chiefly of neoblasts of plagioclase, clinopyroxene, and amphibole. The protolith was probably a two-pyroxene gabbronorite or olivine gabbronorite. There are a few iron-titanium oxide-rich layers.

Lithologic Unit II consists of 140.5 m of olivine and olivine-bearing gabbro. The upper contact is drawn at the first appearance of clearly igneous textures, and the lower boundary is a rapid transition to gabbro with more orthopyroxene and more sodic plagioclase. Most of the rocks are mesocumulates. Alternating bands of olivine-rich and olivine-poor gabbro reflect rare modal layering. Chemically, these gabbros are fairly primitive. Interlayered iron-titanium oxide-bearing gabbros are present, as are a few pyroxene-rich layers. Some mylonitic and porphyroclastic intervals are present, particularly in the upper part of the unit.

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[1] Robinson, P. T., Von Herzen, R. P., et al., 1989. *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program).

[2] Shipboard Scientific Party is as given in List of Participants preceding the contents.

Lithologic Unit III is a 44-m-thick sequence of olivine gabbro with intervals of iron-titanium oxide gabbro. These gabbros are macroscopically similar to those of Unit II but have significantly more evolved compositions. The upper contact is gradational and is defined mineralogically, but also coincides with a change in chemical composition. A well-developed igneous lamination is steeply dipping in the upper part of the unit but flattens with depth. Mylonitic and foliated zones are common, and the lower contact of Unit III is marked by a 60-cm-thick zone of mylonite.

Lithologic Unit IV is made up of 48 m of iron-titanium oxide-rich gabbro. The upper contact grades into Unit III, and the lower boundary is marked by a 3-m-thick layer of mylonite. These gabbros have more abundant opaque minerals (10% or more) and less olivine than those of Unit III; $Fe_2O_3$ contents can be as high as 30 wt%, and $TiO_2$ contents can be as high as 9 wt%. A felsic intrusion breccia having trondjhemite veins occurs at two levels in the unit.

Lithologic Unit V consists of 131.5 m of relatively uniform olivine gabbro characterized by a scarcity of iron-titanium oxides and low-calcium pyroxene. Most of the gabbros are mesocumulates, and some exhibit primary grain-size layering. They are mineralogically and chemically similar to those of Unit II. Thin troctolite layers and several plagioclase-rich zones are evident. Zones of brecciation are common and contain felsic veins with epidote and albite.

Lithologic Unit VI is a 97.2-m-thick interval of olivine-rich gabbro having frequent layers of troctolite. The gabbros are similar to those of Unit V but are more olivine-rich. The troctolite and troctolitic gabbros are interlayered with the olivine gabbros, and these were interpreted as intrusive layers. These gabbros are the most mafic rocks encountered in Hole 735B. A few coarse-grained iron-titanium oxide gabbros also are present. Unit VI also has frequent intervals of metagabbro characterized by mylonitic to porphyroclastic textures.

Veins and fractures generally dip 40° to 90°, with a strong peak at 60° to 65°. The mean dip of both veins and foliation decreases downward in the hole, suggesting that deformation took place along listric normal faults that flatten downward.

The rocks from Hole 735B were subjected to varying degrees of metamorphism and alteration. An early stage of dynamothermal metamorphism produced highly foliated porphyroclastic, gneissic, and mylonitic textures. This high-temperature event was followed by brecciation and static alteration associated with brittle deformation. The static alteration was controlled by permeability and is manifested by numerous veins, from 0.5 mm to 2 cm wide, filled largely with hornblende and sodic plagioclase. Clinozoisite, epidote, and minor prehnite occur in the lower parts of the core. A few silicic veins containing diopside, hornblende, sphene, clinozoisite, and albite are also present. In undeformed gabbros, static alteration resulted in development of coronas of hornblende, tremolite, talc, clinozoisite, magnetite, chlorite, sphene, epidote, and phlogopite(?) around the primary igneous minerals. A late stage of oxidative alteration is reflected in carbonate-hematite-smectite pseudomorphs of olivine and orthopyroxene.

Paleomagnetic intensities vary and are generally in the range of other oceanic gabbros, but up to $>2.5$ emu/cm$^3$ in some of the iron-titanium oxide gabbros. Magnetic susceptibilities average about $100 \times 10^{-6}$ cgs. Again, the highest values are in the iron-titanium oxide gabbros. Natural remanent inclinations are all steep, about equally divided between normal and reverse. Stable inclinations are reversed and average 65° ± 15°.

Compressional-wave seismic velocities in the gabbros range from 6.5 to 7.0 km/s. Physical-properties measurements show seismic anisotropy of up to 10%, particularly in some of the foliated rocks. The multichannel seismic experiment indicated that *in-situ* seismic velocity increases somewhat (5%–10%) with depth over the hole. Grain (matrix) densities obtained from logs average about 2.9 g/cm$^3$ over the hole.

The laterolog showed variations of electrical resistivity of four orders of magnitude downhole (~4 to 40,000 ohm-m). The most prominent low-resistivity zone occurs throughout Unit IV and probably results from the effect of the high mineral conductivity of the iron-titanium oxides. Smaller-scale variations (a few meters) in the units below may reflect the same conductivity mechanisms.

The borehole televiewer showed that most of the hole wall is relatively smooth, with occasional linear and sinusoidal features that probably indicate small fractures cutting the borehole.

Four magnetometer sondes were run in the hole: the Schlumberger three-component tool used primarily for hole inclination and orientation, a U.S. Geological Survey (USGS) three-component magnetometer, a USGS susceptibility tool, and a University of Washington/Lamont-Doherty Geological Observatory (UW/LDGO) combined three-component magnetometer and susceptibility tool. The magnetometers showed large and similar variations in the fields measured in the hole, especially in the iron-titanium oxide-rich zone, where the fields are as much as 50% greater and more variable. Susceptibility is also more variable in this zone.

A borehole packer experiment indicated low fluid permeability below about 272 mbsf, with higher values (by several orders of magnitude) above this level. The temperature log showed a very low, or even negative, gradient in the hole, which further suggests the effects of seawater advection, even with low porosity.

More comprehensive studies of the rock samples recovered and the data obtained should better define the origin, tectonics, and physical state of this unique section of material, which we believe represents the lower oceanic crust.

## BACKGROUND AND SCIENTIFIC OBJECTIVES

By 13 November 1987, we had spent three weeks searching without success for a location in which to deploy the hard-rock guidebase for drilling a deep hole in peridotite. Attempts to drill at Sites 732, 733, and 734 (Fig. 1) had been frustrated by accumulations of rubble and sediment or by slopes too steep for the hard-rock guidebase. Three remaining backup sites, discussed in the scientific prospectus, included (1) the sediment-filled basins on the floor of the transform, (2) the active nodal basin, and (3) a sediment-filled basin in the northern part of the transform. The sediment-filled basins in the active transform were eliminated from consideration because we thought they might be underlain by the same type of gravel deposits that could not be drilled at Site 732.

We considered the active nodal basin to be of high scientific interest but did not select it because it is a bare-rock site in deep water (5500 m) and thus could not be sampled adequately in the time remaining for Leg 118. Furthermore, our experience in the transform until then suggested that there might be coarse talus deposits in the nodal basin that would be difficult or impossible to drill. We seriously considered the sediment-filled basin, but because we still wished to deploy the guidebase to drill a reentry hole for sampling and logging, we moved to a shoal bench on the east wall of the transform, where the topography indicated many flat surfaces suitable for guidebase deployment. In other transform faults, such shoal features are commonly underlain by mantle peridotite. Because of the short time remaining for the leg, a shallow-water site seemed to have several operational advantages.

After obtaining permission to drill this site, we deployed a beacon and conducted a short television/sonar survey. The survey revealed numerous relatively flat outcrops of foliated igneous rock, separated by small sediment ponds. A test spud-in at Hole 735A recovered a small amount of gabbro. Consequently, we deployed the hard-rock guidebase in preparation for drilling a deep reentry hole.

The principal objectives at Site 735 were (1) to sample a section of basement rock on the wall of the transform, (2) to conduct an array of downhole measurements, and (3) to test the engineering of the hard-rock guidebase and bare-rock drilling capabilities of *JOIDES Resolution*.

## GEOLOGIC AND TECTONIC SETTING

Site 735 is located on a shallow platform on the east wall of the Atlantis II Fracture Zone (Fig. 1). This site lies near the center of a remarkably flat area, about 9 km long and 4 km wide, that is elongated in a north-south direction. The top of this feature lies at a water depth of just over 700 m, making it the shal-

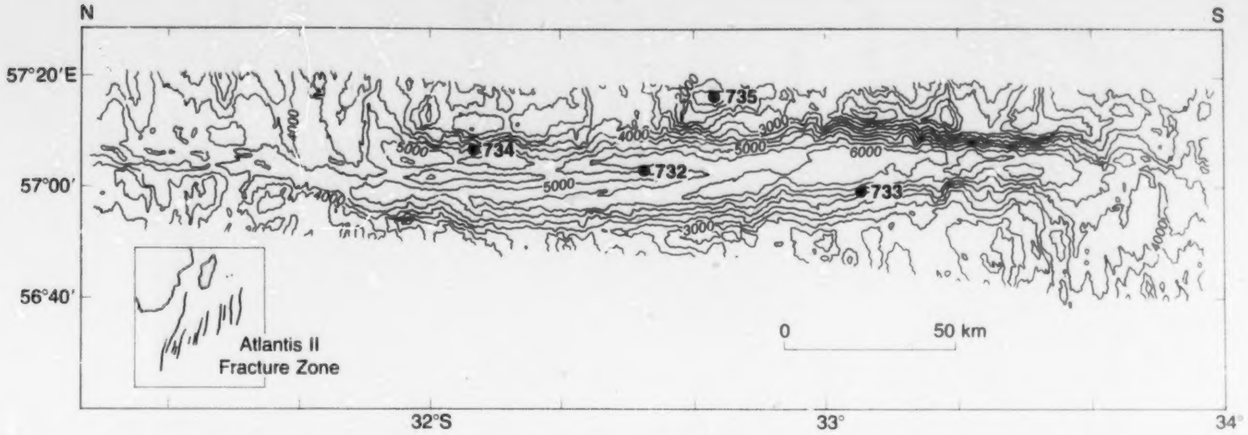

Figure 1. Bathymetric map at 500-m contour intervals of the Atlantis II Fracture Zone, Southwest Indian Ridge, showing Leg 118 drill sites. Survey from *Conrad* cruise 27-09, 1986 (H. Dick, Chief Scientist, with D. Gallo and R. Tyce).

lowest feature associated with the fracture zone. The extremely flat surface of this platform suggests that it is a wave-cut feature that has subsided since formation to its present position. The magnetic anomaly pattern on the east wall of the transform suggests a crustal age of about 12 Ma for this site.

A television/sonar survey of the seafloor in the vicinity of Site 735, conducted from the *JOIDES Resolution*, revealed basement outcrops locally mantled with thin layers of sediment. Many of these outcrops have a well-developed, steeply dipping foliation and are cut by a regular pattern of faults or joints. Subsequent drilling revealed that the exposed basement consists of highly deformed gabbro.

Current models for ridge crest dynamics (e.g., Schouten and Klitgord, 1982) call for a series of ridge segments, each of which is underlain by an axial magma chamber. We believe the fracture zones are relatively cold zones that receive magma largely by lateral injection along the spreading ridge. In this model the far edges of spreading cells (i.e., fracture zones) will have considerably thinner crust sections than the central parts because they will receive less magma. Because of the thin crustal sections and extensive vertical tectonics associated with fracture zones, lower crustal and mantle rock are commonly exposed on the walls of these features.

Site 735 is located on the shoalest of a series of uplifted blocks that are connected by saddles that make up a long, linear ridge parallel to the transform. The entire ridge is elevated from 2 to nearly 6 km relative to the floor of the adjacent transform and from 1 to 4 km relative to the ridge-generated crust lying to the east. The topographic relief along this "transverse ridge" varies considerably, particularly between uplifted blocks, which may be as much as 2 or 3 km higher than the intervening saddles. The uplifted blocks are highly irregular in shape, defined by steep slopes commonly associated with major normal faulting in such terrains, and may represent simple horsts uplifted relative to both the rift valley floor at which the crust originated and the adjacent ocean crust to the east.

Such anomalous topographic features are common features of fracture zones, which in many cases are underlain by upper mantle and lower crustal rocks (Bonatti, 1978; Engel and Fisher, 1975; van Andel et al., 1971). For example, St. Peter and Paul rocks, located on the St. Paul Fracture Zone have a tectonic setting analogous to that at Site 735 and are underlain by similar lithologies. An uplifted block in the Owen Fracture Zone, near its intersection with the Mid-Indian Ridge, exposes mantle lherzolites, harzburgites, and dunites (Bonatti and Hamlyn, 1978). Many other large fracture zones have similar topographic highs (transverse ridges) underlain by lower crustal and mantle rocks (Bonatti, 1978).

Little is known regarding the processes by which these anomalous topographic features are formed. Uplift of such blocks has been attributed to a combination of thermal conduction across fracture zones from ridge-transform intersections, to compressional and tensional stresses associated with transform faulting, to reduction of the lithospheric head resulting from the thinner crustal sections in transforms, and to serpentinite diapirism. Any or all of these may be contributing factors.

## OPERATIONS

### Introduction

This site was selected for drilling on the basis of our somewhat meager understanding of the geology and tectonics of other oceanic transform faults, and because of the time and operational constraints that remained for Leg 118. The site is the shallowest region in the vicinity of the Atlantis II Transform, a relatively flat platform at a water depth of about 700 m on the highest part of the eastern wall (Fig. 1). The platform is about 9 km long in the north-south direction and 4 km wide. Its unusual flatness (< 100 m) at minimum depth suggests that it has been wave-cut at sea level and subsequently subsided.

By analogy with other transform faults having high walls, we believed that this site offered a good possibility for drilling ultrabasic or abyssal rock that had been emplaced to high levels. The shallow depth also made operational constraints less demanding, especially because less than four weeks of the leg remained at the time we considered this site to achieve one of our primary objectives of drilling and coring a deep basement hole. The shallow depth meant that deployment of the hard-rock guidebase and round trips of the drill string to change bits, etc., would take much less time. Although the site was not in the original prospectus for the leg, it was approved on the basis of these scientific objectives and logistical constraints.

### Approach to Site 735

The site location required a transit of 8.5 hr from Site 734. (All times are local unless stated otherwise.) As usual, we planned to use the seismic-reflection profiling system for both reliable depth soundings and for detection of possible sub-bottom reflectors. This equipment was deployed about 3 km before reaching the first turning point of the beacon location survey (Fig. 2),

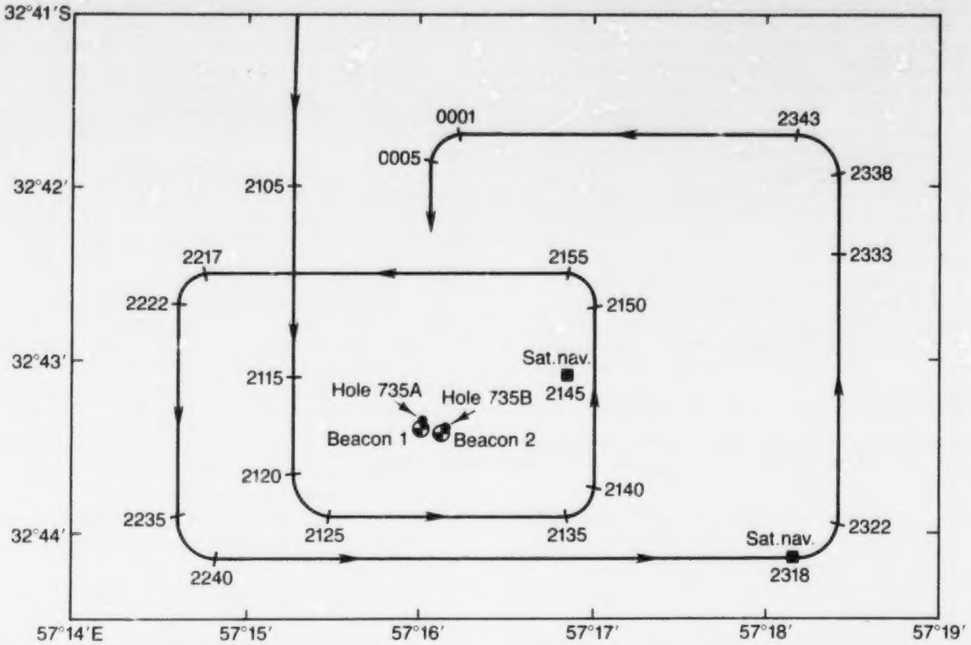

Figure 2. Track line followed until beacon deployment during approach to Site 735. Times along track line are local (UTC + 4 hr) for 13 and 14 November 1987. Navigation was controlled by transit satellite fixes. Beacon and hole locations are indicated. Track line after 0005 hr, 14 November, varied before beacon deployment.

and the ship was slowed to 5-6 kt. Unfortunately, global positioning system (GPS) navigation was not available during this survey, and we had to rely on occasional transit satellite fixes and dead reckoning. Hence, the survey was planned to include several transverse crossings of the shallow platform to confirm its location and geometry, especially since Sea Beam coverage of this feature during the site-survey cruise for this leg was incomplete (H. Dick, pers. comm., 1987).

We crossed the platform at three different locations during the pre-beacon survey. This platform has a relatively flat surface with some occasional irregularities <20 m high (Fig. 3). We planned to stop over the platform after the last crossing, retrieve the seismic profiling gear, and lower the television/sonar to determine the nature of the bottom before deploying the beacon. Unfortunately, the ship drifted off the platform into deeper water during retrieval of the seismic gear and before television/sonar deployment, and we had to wait for 1 hr for another satellite position fix to find our way back to the platform. We then deployed a recallable beacon at 32°43.4′S, 57°15.9′E, over slightly irregular bottom topography for a reference position for the television/sonar survey.

As part of the departure from the site, another brief survey was conducted after logging Hole 735B to determine the exact location of the drill site relative to the east and west slopes of the platform. Again, GPS was not available, but we were able to use the beacon left behind as a relatively accurate reference point for dead reckoning. The site is located approximately 500 m east of the upper slope of the west wall.

## Television/Sonar Surveys

After deploying the beacon, a simple box survey, 200 m on a side, was conducted around it to determine the nature of the bottom. The survey revealed irregular outcrops of dark, sometimes foliated rock separated by apparently thin patches of light-colored sediment (Fig. 4). The outcrops of rock protruded only slightly (< few meters) above the level of the sediment patches, and depths varied smoothly over a range of about 30 m along the survey track, deeper to the southwest. This survey took about 4 hr (between 2300 hr UTC, 13 November, and 0300 hr, 14 November 1987), and was relatively straightforward in that the camera remained closely under the ship in the shallow water and moved at relatively slow survey speeds.

## Hole 735A (32°43.3′S, 57°15.9′E)

A test spud-in was performed 100 m north and 30 m east of the beacon (Fig. 4) using the positive displacement coring motor (PDCM). The bottom was stable and very hard, with 7 m cored in 11.6 hr before the bit stopped advancing (Table 1). The core barrel could not be pulled with the wireline, so the pipe was tripped to the surface. The pin of the bit sub had failed leaving the bit in the hole. A total of 0.1 m of gabbro was recovered.

Shipboard engineering and operations personnel advised that this site was stable and could be drilled but warned that the coring rate probably would be only one or two cores per day. We decided to deploy the hard-rock guidebase and to drill as deeply as possible in the time remaining.

## Hole 735B (32°43.395′S, 57°15.959′E)

Assembly of the hard-rock guidebase began at 1300 hr on 15 November and was completed 42 hr later on 17 November; the entire operation proceeded almost flawlessly. We had to deploy a second acoustic beacon late on 15 November, when the first beacon began to fail. This second beacon landed 230 m away in a southeast direction (Fig. 4), which necessitated moving the ship. Consequently, another brief television/sonar survey was run to confirm the nature of the bottom. The guidebase was landed 50 m north and 50 m east of the second beacon (Fig. 4), about 500 m from the break of slope of the transform valley wall.

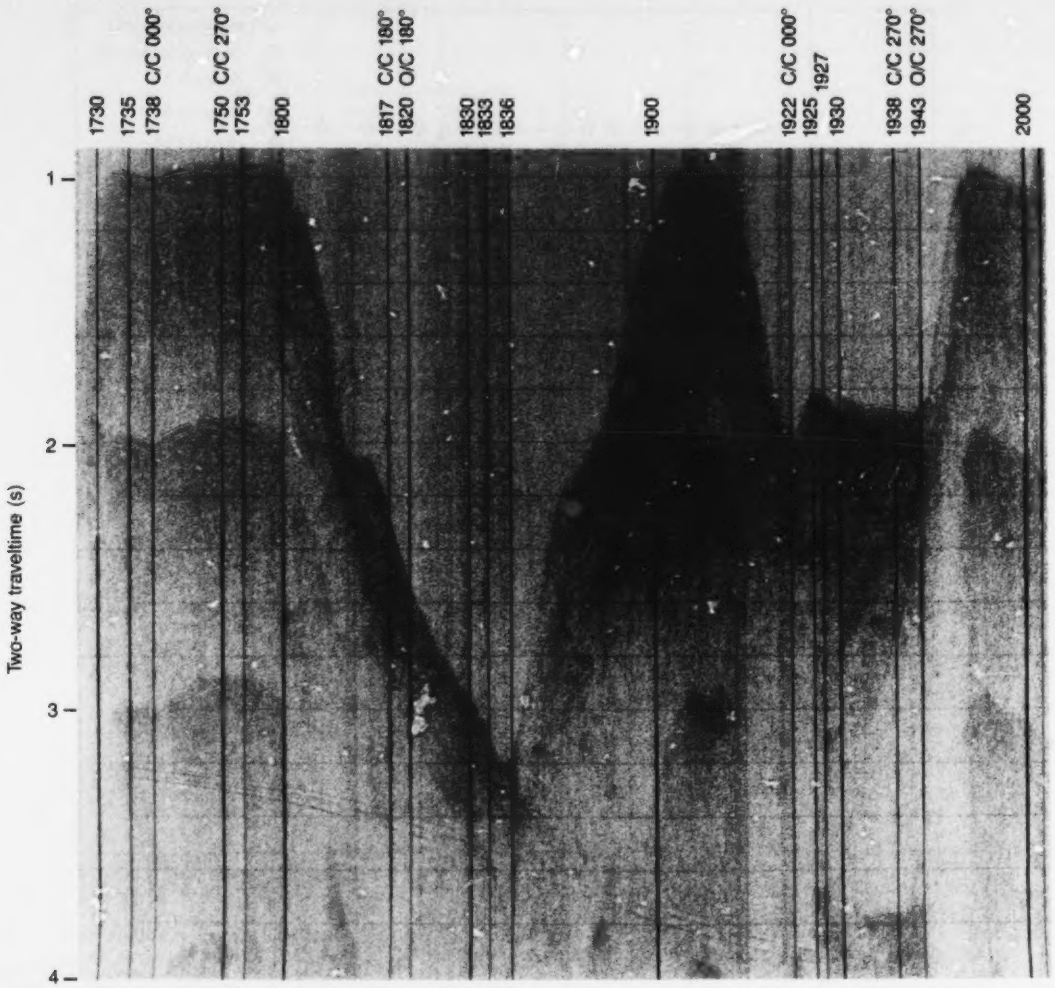

Figure 3. Recording from seismic-reflection profiling system during pre-beacon deployment survey at Site 735 (Fig. 2). Source is a water gun, with recording filtered between 80–250 Hz. Recording window after "shot" is 0 to 4 s. Times printed on recording are UTC, 13 November 1987. c/c = change course.

Table 1 summarizes the drilling and coring operations for Hole 735B. The PDCM was used for the initial unsupported spud-in. As expected, the coring rate was low. Bit 1 advanced the hole 6.5 m (0–6.5 mbsf) in 13 hr. A total of 2.3 m of foliated metagabbro was recovered. The recovery rate for the bit was 35.4%. Once the guidebase had been deployed, we could no longer consider the hole expendable, and consequently, we decided to be prudent and conservative in the number of hours each bit was run. Thus, the first bit was pulled after the first core.

Bit 2 advanced the hole by 14.5 m (6.5–21.0 mbsf) in 14.8 hr. A total of 6.25 m of foliated metagabbro was recovered. The average recovery rate for the bit was 43.1%. When the bit was returned to the surface, we found it was not seriously worn.

Bit 3 was a hybrid bit; the core guide between the cones was composed of geoset diamonds. These guides are designed to trim the core and guide it into the grasp of the core catcher. The bit advanced 18.2 m (21.0–39.2 mbsf) in 14.0 hr. A total of 5.56 m of foliated and massive gabbro was recovered. When the bit was tripped to the surface, we found the cones were in good condition, but the diamonds were severely worn and chipped. The average recovery rate for the bit was 30.5%.

Bit 4 was a Christensen impregnated diamond bit of a design commonly used in the mining industry. However, one this size had never been used for hard-rock drilling. The bit was run for 2.25 hr and advanced the hole 0.2 m (39.2–39.4 mbsf). It was then returned to the surface after a period when no penetration was evident at the rig floor. A total of 0.08 m of gabbro was recovered in the core catcher. The bit was badly worn, and it was clear that this particular design was no match for hard and abrasive gabbro. The recovery rate for this bit was 40.0%.

The diamond bit run terminated at 39.4 mbsf. We believed that this depth of hole was sufficient to justify the running of a rotary-driven bottom-hole assembly (BHA).

The first rotary-driven 9.875 in. bit (bit 5, a Rock Bit Industries type C-7) was run with only 15,000 lb of weight to reduce BHA flexure. Despite its light weight, this bit advanced 16.8 m (39.4–56.2 mbsf) in 19 hr. A total of 13.31 m of foliated and massive gabbro was recovered. The average recovery rate for the bit was 79.2%, a significant increase over the 36.02% average recovery rate of the motor-driven system.

Bit 6 advanced the hole by 12.3 m (56.2–68.5 mbsf). A total of 8.43 m of foliated and massive gabbro was recovered. The average recovery rate for the bit was 68.5%.

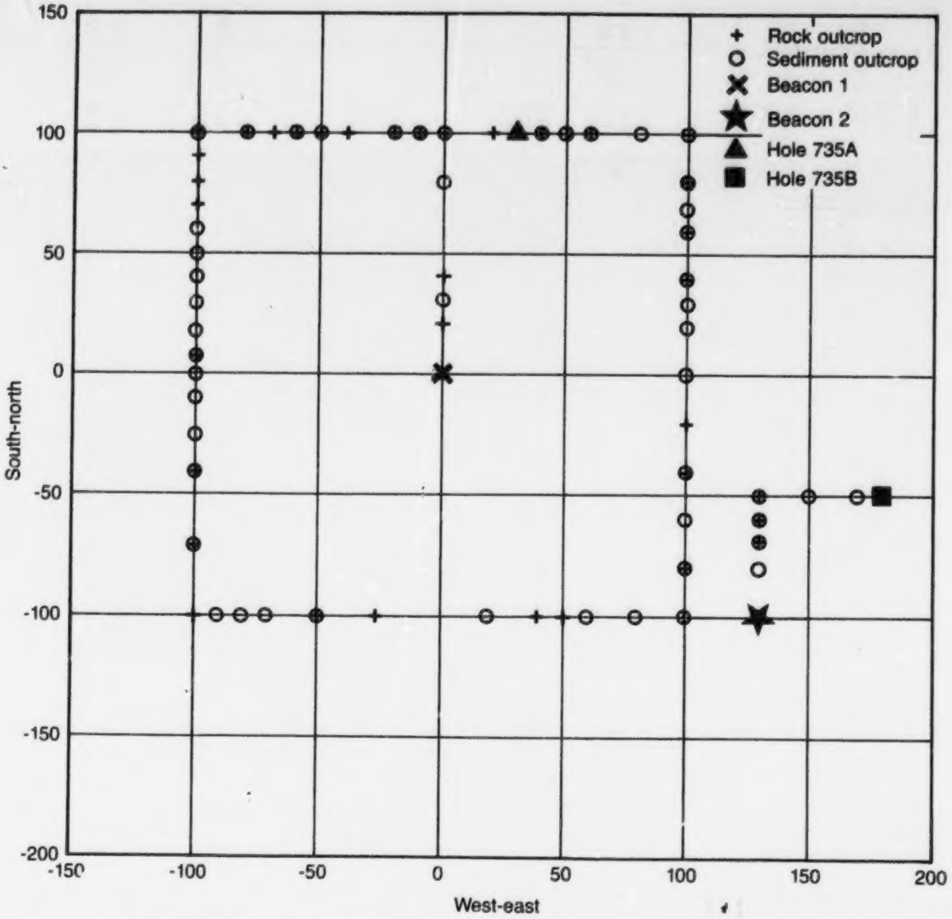

Figure 4. Local survey with television/sonar system at Site 735. Small symbols indicate occurrences of bottom types as recorded on log made during survey. Axes are in meters distance from Beacon 1. Drill-hole locations are as shown.

Table 1. Drilling and coring summary at Site 735.

| Core | Date (Nov./Dec. 1987) | Time (local) | Total depth (mbrf) | Depth (mbsf) | Length advanced (m) | Length cored (m) | Length recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| 118-735A-1D | 15 | 0900 | 738.0–745.0 | 0–7.0 | 7.0 | 7.0 | 0.10 | 1.4 |
| 118-735B-1D | 18 | 0615 | 731.0–737.5 | 0–6.5 | 6.5 | 6.5 | 2.30 | 35.4 |
| 2D | 18 | 2000 | 737.5–745.5 | 6.5–14.5 | 8.0 | 8.0 | 3.00 | 37.5 |
| 3D | 18 | 2315 | 745.5–748.5 | 14.5–17.5 | 3.0 | 3.0 | 1.50 | 50.0 |
| 4D | 19 | 0550 | 748.5–752.0 | 17.5–21.0 | 3.5 | 3.5 | 1.75 | 50.0 |
| 5D | 19 | 1200 | 752.0–755.0 | 21.0–24.0 | 3.0 | 3.0 | 0.28 | 9.3 |
| 6D | 19 | 1600 | 755.0–757.0 | 24.0–26.0 | 2.0 | 2.0 | 0.94 | 47.0 |
| 7D | 19 | 2010 | 757.0–760.2 | 26.0–29.2 | 3.2 | 3.2 | 1.30 | 40.6 |
| 8D | 19 | 2330 | 760.2–764.2 | 29.2–33.2 | 4.0 | 4.0 | 0.75 | 18.6 |
| 9D | 20 | 0300 | 764.2–767.2 | 33.2–36.2 | 3.0 | 3.0 | 1.02 | 34.0 |
| 10D | 20 | 0730 | 767.2–770.2 | 36.2–39.2 | 3.0 | 3.0 | 1.27 | 42.0 |
| 11D | 20 | 2100 | 770.2–770.4 | 39.2–39.4 | 0.2 | 0.2 | 0.08 | 40.0 |
| 12R | 21 | 0845 | 770.4–775.5 | 39.4–44.5 | 5.1 | 5.1 | 4.01 | 78.6 |
| 13R | 21 | 1715 | 775.5–782.2 | 44.5–51.2 | 6.7 | 6.7 | 4.22 | 63.0 |
| 14R | 22 | 0200 | 782.2–787.2 | 51.2–56.2 | 5.0 | 5.0 | 5.08 | 101.6 |
| 15R | 22 | 1335 | 787.2–792.8 | 56.2–61.8 | 5.6 | 5.6 | 2.81 | 50.2 |
| 16R | 22 | 2115 | 792.8–798.0 | 61.8–67.0 | 5.2 | 5.2 | 5.26 | 101.2 |
| 17R | 23 | 0200 | 798.0–799.5 | 67.0–68.5 | 1.5 | 1.5 | 0.36 | 24.0 |
| 18R | 23 | 1220 | 779.5–805.7 | 68.5–74.7 | 6.2 | 6.2 | 3.40 | 54.8 |
| 19R | 23 | 1910 | 805.7–815.2 | 74.7–84.2 | 9.5 | 9.5 | 5.58 | 58.7 |
| 20R | 23 | 2330 | 815.2–820.2 | 84.2–89.2 | 5.0 | 5.0 | 3.00 | 60.0 |
| 21R | 24 | 0615 | 820.2–825.0 | 89.2–94.0 | 4.8 | 4.8 | 2.86 | 57.2 |
| 22R | 24 | 1400 | 825.0–831.5 | 94.0–100.5 | 6.5 | 6.5 | 4.76 | 73.2 |
| 23R | 24 | 1815 | 831.5–836.5 | 100.5–105.5 | 5.0 | 5.0 | 5.00 | 100.0 |

Table 1 (continued).

| Core | Date (Nov./Dec. 1987) | Time (local) | Total depth (mbrf) | Depth (mbsf) | Length advanced (m) | Length cored (m) | Length recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| 118-735B-24R | 24 | 2230 | 836.5–841.5 | 105.5–110.5 | 5.0 | 5.0 | 4.47 | 89.4 |
| (Cont.) 25R | 25 | 0130 | 841.5–846.5 | 110.5–115.5 | 5.0 | 5.0 | 3.69 | 73.8 |
| 26R | 25 | 0650 | 846.5–852.5 | 115.5–121.5 | 6.0 | 6.0 | 5.74 | 95.7 |
| 27R | 25 | 1115 | 852.5–857.5 | 121.5–126.5 | 5.0 | 5.0 | 4.71 | 94.2 |
| 28R | 25 | 1545 | 857.5–862.5 | 126.5–131.5 | 5.0 | 5.0 | 5.03 | 100.6 |
| 29R | 26 | 0300 | 862.5–867.5 | 131.5–136.5 | 5.0 | 5.0 | 4.16 | 83.2 |
| 30R | 26 | 0645 | 867.5–874.5 | 136.5–143.5 | 7.0 | 7.0 | 5.80 | 82.8 |
| 31R | 26 | 1000 | 874.5–879.5 | 143.5–148.5 | 5.0 | 5.0 | 5.16 | 103.2 |
| 32R | 26 | 1230 | 879.5–884.5 | 148.5–153.5 | 5.0 | 5.0 | 4.65 | 93.0 |
| 33R | 26 | 1715 | 884.5–889.5 | 153.5–158.5 | 5.0 | 5.0 | 5.00 | 100.0 |
| 34R | 26 | 2015 | 889.5–894.5 | 158.5–163.5 | 5.0 | 5.0 | 3.96 | 79.2 |
| 35R | 27 | 0525 | 894.5–902.0 | 163.5–171.0 | 7.5 | 7.5 | 7.97 | 106.3 |
| 36R | 27 | 1220 | 902.0–907.0 | 171.0–176.0 | 5.0 | 5.0 | 4.78 | 95.6 |
| 37R | 27 | 1420 | 907.0–912.0 | 176.0–181.0 | 5.0 | 5.0 | 3.88 | 77.6 |
| 38R | 27 | 1745 | 912.0–917.0 | 181.0–186.0 | 5.0 | 5.0 | 5.78 | 105.6 |
| 39R | 27 | 1945 | 917.0–922.0 | 186.0–191.0 | 5.0 | 5.0 | 4.24 | 84.8 |
| 40R | 27 | 2215 | 922.0–927.0 | 191.0–196.0 | 5.0 | 5.0 | 4.92 | 98.4 |
| 41R | 28 | 0030 | 927.0–932.0 | 196.0–201.0 | 5.0 | 5.0 | 4.18 | 83.6 |
| 42R | 28 | 0300 | 932.0–937.0 | 201.0–206.0 | 5.0 | 5.0 | 5.10 | 102.0 |
| 43R | 28 | 0515 | 937.0–942.0 | 206.0–211.0 | 5.0 | 5.0 | 4.68 | 93.6 |
| 44R | 28 | 0745 | 942.0–947.0 | 211.0–216.0 | 5.0 | 5.0 | 4.93 | 98.6 |
| 45R | 28 | 1000 | 947.0–952.0 | 216.0–221.0 | 5.0 | 5.0 | 5.19 | 103.8 |
| 46R | 28 | 1245 | 952.0–957.0 | 221.0–226.0 | 5.0 | 5.0 | 5.15 | 103.0 |
| 47R | 28 | 1500 | 957.0–962.0 | 226.0–231.0 | 5.0 | 5.0 | 4.87 | 97.4 |
| 48R | 28 | 1745 | 962.0–967.0 | 231.0–236.0 | 5.0 | 5.0 | 4.76 | 95.2 |
| 49R | 28 | 1930 | 967.0–969.0 | 236.0–238.0 | 2.0 | 2.0 | 2.52 | 126.0 |
| 50R | 29 | 0510 | 969.0–974.0 | 238.0–243.0 | 5.0 | 5.0 | 5.28 | 105.6 |
| 51R | 29 | 0715 | 974.0–979.0 | 243.0–248.0 | 5.0 | 5.0 | 4.46 | 89.2 |
| 52R | 29 | 0950 | 979.0–984.0 | 248.0–253.0 | 5.0 | 5.0 | 4.89 | 97.8 |
| 53R | 29 | 1405 | 984.0–989.0 | 253.0–258.0 | 5.0 | 5.0 | 5.23 | 104.6 |
| 54R | 29 | 1840 | 989.0–996.0 | 258.0–265.0 | 7.0 | 7.0 | 6.98 | 99.7 |
| 55R | 29 | 2210 | 996.0–1001.0 | 265.0–270.0 | 5.0 | 5.0 | 4.67 | 93.4 |
| 56R | 30 | 0150 | 1001.0–1006.0 | 270.0–275.0 | 5.0 | 5.0 | 4.19 | 83.8 |
| 57R | 30 | 0415 | 1006.0–1011.5 | 275.0–280.5 | 5.5 | 5.5 | 5.10 | 93.0 |
| 58R | 30 | 0710 | 1011.5–1016.5 | 280.5–285.5 | 5.0 | 5.0 | 3.74 | 74.8 |
| 59R | 30 | 0910 | 1016.5–1021.5 | 285.5–290.5 | 5.0 | 5.0 | 4.90 | 98.0 |
| 60R | 30 | 1115 | 1021.5–1026.5 | 290.5–295.5 | 5.0 | 5.0 | 5.20 | 104.0 |
| 61R | 30 | 1400 | 1026.5–1031.5 | 295.5–300.5 | 5.0 | 5.0 | 5.15 | 103.0 |
| 62R | 30 | 1630 | 1031.5–1036.5 | 300.5–305.5 | 5.0 | 5.0 | 5.08 | 101.6 |
| 63R | 01 | 0300 | 1036.5–1046.0 | 305.5–315.0 | 9.5 | 9.5 | 8.84 | 93.1 |
| 64R | 01 | 0445 | 1046.0–1051.0 | 315.0–320.0 | 5.0 | 5.0 | 5.24 | 104.8 |
| 65R | 01 | 0630 | 1051.0–1056.0 | 320.0–325.0 | 5.0 | 5.0 | 3.37 | 74.6 |
| 66R | 01 | 0800 | 1056.0–1061.0 | 325.0–330.0 | 5.0 | 5.0 | 3.95 | 79.0 |
| 67R | 01 | 0930 | 1061.0–1066.0 | 330.0–335.0 | 5.0 | 5.0 | 4.67 | 93.4 |
| 68R | 01 | 1130 | 1066.0–1072.0 | 335.0–341.0 | 5.0 | 5.0 | 3.00 | 50.0 |
| 69R | 01 | 1320 | 1072.0–1077.0 | 341.0–346.0 | 5.0 | 5.0 | 5.55 | 111.0 |
| 70R | 01 | 1440 | 1077.0–1082.0 | 346.0–351.0 | 5.0 | 5.0 | 4.76 | 95.2 |
| 71R | 01 | 1625 | 1082.0–1087.0 | 351.0–356.0 | 5.0 | 5.0 | 5.07 | 101.4 |
| 72R | 01 | 1930 | 1087.0–1096.5 | 356.0–365.5 | 9.5 | 9.5 | 9.20 | 96.8 |
| 73R | 01 | 2200 | 1096.5–1106.0 | 365.5–375.0 | 9.5 | 9.5 | 9.00 | 94.7 |
| 74R | 02 | 0030 | 1106.0–1115.5 | 375.0–384.5 | 9.5 | 9.5 | 9.78 | 102.9 |
| 75R | 02 | 0400 | 1115.5–1125.0 | 384.5–394.0 | 9.5 | 9.5 | 9.81 | 103.2 |
| 76R | 02 | 0700 | 1125.0–1134.5 | 394.0–403.5 | 9.5 | 9.5 | 8.62 | 90.8 |
| 77R | 02 | 1045 | 1134.5–1140.5 | 403.5–409.5 | 6.0 | 6.0 | 5.84 | 97.3 |
| 78R | 02 | 1345 | 1140.5–1145.5 | 409.5–414.5 | 5.0 | 5.0 | 5.30 | 106.0 |
| 79R | 03 | 0200 | 1145.5–1155.0 | 414.5–424.0 | 9.5 | 9.5 | 9.34 | 98.3 |
| 80R | 03 | 0615 | 1155.0–1164.5 | 424.0–433.5 | 9.5 | 9.5 | 9.70 | 102.1 |
| 81R | 03 | 0940 | 1164.5–1174.0 | 433.5–443.0 | 9.5 | 9.5 | 8.70 | 91.6 |
| 82R | 03 | 1230 | 1174.0–1183.5 | 443.0–452.5 | 9.5 | 9.5 | 8.57 | 90.2 |
| 83R | 03 | 1610 | 1183.5–1193.0 | 452.5–462.0 | 9.5 | 9.5 | 9.90 | 104.2 |
| 84R | 03 | 1920 | 1193.0–1202.5 | 462.0–471.5 | 9.5 | 9.5 | 8.87 | 93.4 |
| 85R | 03 | 2320 | 1202.5–1212.0 | 471.5–481.0 | 9.5 | 9.5 | 9.57 | 100.7 |
| 86R | 04 | 0215 | 1212.0–1221.5 | 481.0–490.5 | 9.5 | 9.5 | 8.76 | 92.2 |
| 87R | 04 | 0505 | 1221.5–1231.0 | 490.5–500.0 | 9.5 | 9.5 | 8.12 | 85.5 |
| 88N | 04 | 1925 | 1231.0–1231.7 | 500.0–500.7 | 0.7 | 0.7 | 0.70 | 100.0 |
| [a]735C-1N | 04 |  | 753.9–753.9 | 0–0 | 0 | 0 | 0 | 0 |

[a] Unable to drill, navidrill core barrel bent.

Bit 7 advanced the hole 25.5 m (68.5–94.0 mbsf) in 18.5 hr. A total of 14.84 m of foliated and massive gabbro was recovered. A noticeable increase in the rate of penetration and recovery became evident. The average recovery rate for this bit was 58.2%.

Bit 8 advanced the hole 37.5 m (94.0–131.5 mbsf) in 24.67 hr. A total of 33.4 m of foliated and massive gabbro was recovered. The average recovery rate for the bit was 89.1%.

Bit 9 advanced the hole 39.5 m (131.5–171.0 mbsf) in 24 hr. A total of 36.7 m of massive gabbro and massive olivine-bearing gabbro was recovered. Bit weight during this run was increased from 15,000 to 22,000 lb. The average recovery rate for the bit was 92.9%.

Bit 10 advanced the hole 67.0 m (171.0-238.0 mbsf) in 38 hr. A total of 64.48 m of massive gabbro, massive olivine-bearing gabbro, and iron-titanium oxide gabbro was recovered. The average recovery rate for the bit was 96.2%.

Bit 11, the last available Type C-7 bit, advanced the hole 67.5 m (238.0-305.5 mbsf) in 30 hr. A total of 64.87 m of massive gabbro and iron-titanium oxide gabbro, veined by trondhjemite, was recovered. The average recovery rate for this bit was 96.1%.

Bit 12, a Type C-57 bit, advanced the hole 109.0 m (305.5-414.5 mbsf) in 29.17 hr. A total of 102.36 m of massive olivine gabbro containing a 4-m-thick brecciated zone and mylonitized gabbro below 403.5 mbsf was recovered. The breccia is filled with massive epidote veins that form a stockwork. The average recovery rate for this bit was 93.9%.

Time available for coring became short. The final bit (Bit 13) was run into the hole on 2 December. By this time, essentially all DSDP/ODP records for coring and recovery of hard rock had been broken, but the depth reached was only 414.5 mbsf, and the prospect of a 0.5-km hole was a tantalizing goal. Progress was good until Core 118-735B-85R (471.5-481.0 mbsf), when the penetration rate decreased and it took 195 min to cut 9.5 m. The prospect of reaching 500 mbsf in the assigned coring time was not good, but the next core, Core 118-735B-86R (481.0-490.5 mbsf), was drilled more quickly and took only 145 min to cut 9.5 m. Our allocated coring time ran out, but the logging scientists "loaned" the drillers the few additional hours required to cut a final core, Core 118-735B-87R (490.5-500.0 mbsf), which took the hole to the goal of 0.5 km depth. This core arrived on deck at 0505 hr on 3 December. A total of 81.53 m of massive olivine gabbro containing zones of troctolite and foliated metagabbro were recovered from the 85.5 m cored (414.5-500.0 mbsf) with this bit in 39 hr. The average recovery rate was 95.4%.

Hole 735B was cored from 0 to 500.0 mbsf using the PDCM and rotary top drive systems. Total recovery for the hole was 434.81 m, an average recovery rate of 86.79%. Recovery with the rotary system alone was 420.62 m, an average recovery rate of 91.28%.

### Navidrill Testing in Hole 735B

A period of 24 hr was set aside for testing the navidrill. This system complements the advanced piston corer (APC)/extended-core barrel (XCB) system. A mud-driven motor with a 5-m-long core barrel attached to the bottom is landed inside the bottom drill collar directly above the bit. The core barrel has a thin-walled diamond bit at the bottom that can drill out ahead of the drill pipe. The system is designed to obtain a sample of basement rock at the end of an XCB hole. The tool worked well during land tests but failed two previous tests at sea.

After extensive surface testing, the navidrill cut a 0.7-m-long core in Hole 735B, thereby extending the hole to 500.7 mbsf. A single piece of massive olivine gabbro was recovered. The recovery rate for the navidrill system was 100%. The drill pipe then was pulled above the guidebase, and the ship offset for further test drilling in Hole 735C.

### Hole 735C (32°43.4'S, 57°15.5'E)

We attempted a bare-rock spud-in using the navidrill about 70 m away from Hole 735B, but it was unsuccessful. This failure resulted from the BHA apparently being pumped off the seafloor by the hydraulic force of the drill, which resulted in bending of the inner core barrel. Additional testing time was not available; consequently, the hole was abandoned.

### Logging in Hole 735B

After ending operations at Hole 735C, the ship returned to Hole 735B to conduct a 5.9-day logging program that began the morning of 5 December. A summary of the various logging runs can be found in Table 2.

The first logging run (run 1) was with the Schlumberger DIT/LSS/GR/CAL tool (dual induction/sonic/natural gamma/caliper tool). The tool worked well between 500 and 269 mbsf but an electrical short developed, which resulted in the loss of the induction and caliper (DIT/GR/CAL) part of the data. However, the sonic log ran well throughout. Run 2 was with the Schlumberger LDT/CNTG/NGT/GPIT/AMS tool (litho-density tool/three-component magnetometer), which logged without incident and produced good data. Run 3 was the Schlumberger GST/ACT/CNTG/NGT/GPIT/AMS tool (geochemical combination/magnetometer). Two complete passes were made on capture mode, which gave excellent data; the inelastic mode did not work.

Run 4 was with the Schlumberger DIT/GR/CAL tool, a repeat run of the tool that partially failed earlier (run 1). Results were good, with resistivities varying between 2 ohm-m and the tool maximum of 2000 ohm-m. Run 5 was with the Schlumberger DLL log, which gave excellent data, with resistivities varying between 2 and 40,000 ohm-m. Run 6 was with the USGS temperature log. This gave good results; temperatures were slightly elevated in the upper part of the hole relative to the bottom. Run 7 was with the LDGO borehole televiewer; these tools failed and no data were collected. Run 8 was the LDGO multichannel sonic (MCS) log, which gave good data, except in the top 100 m of the hole. Run 9 was with the USGS magnetometer log, which gave good results. Run 10 was the UW magnetometer/magnetic susceptibility log, which gave good magnetometer data, but the susceptibility data were very noisy. Run 11 was the USGS magnetic susceptibility log, which logged from 490 mbsf to 49 mbsf, worked well, and gave good data. Run 12 was a repeat run of the MCS log to collect data from the top 100 m of the hole. Logging began at 127 mbsf and continued to the seafloor. The resulting data are good. Run 13 was the second run of the USGS temperature tool; the data were consistent with the first temperature log (run 6). Most of the hole had cooled since the first temperature log.

Run 14 was an experiment using the Woods Hole Oceanographic Institution vertical seismic profile (VSP) tool, the first of three runs using this tool. This run was unsuccessful; there were hydraulic clamping problems with the first tool and noise downhole, and the second tool stopped working. To allow time for fixing these tools, the LDGO borehole televiewer was deployed once more during run 15, which logged the full length of the hole. This time, results were good. The shearing of screws holding the centralizer bracket top plates resulted in these being left in the hole. Run 16 was with the Woods Hole VSP, but again the tool failed. To collect VSP information in the hole, the Schlumberger WST (vertical component VSP) tool was deployed during run 17. There was considerable noise downhole, which was compounded by the unusual shallowness of the site, by noise from the ship, and by noise from the drill pipe. We also found it difficult to set the tool in the smooth-sided hole.

Eventually, 22 shot stations were set at about 20-m intervals using both water and air guns. The resulting data are good. The Woods Hole VSP experiment was run for the third time during logging run 18. The problems were alleviated once the tool was set properly. This time, the experiment was a success; 24 clampings at 15-25-m intervals produced good data. Drill pipe was tripped to the surface at 2045 hr on 9 December. The packer was made up and run into the hole, reentering the guidebase at 0145 hr on 10 December. Six successful inflations were conducted be-

**Table 2. Summary of logging operations in Hole 735B.**

| Order/start time [1] | | | Log/experiment |
|---|---|---|---|
| First pipe trip (clean-out/logging bit) | | | |
| | 0800 | 5 December | Reentered hole. |
| (1) | 0930 | 5 December | Schlumberger DIT/LSS/GR/CAL; sonic log good, induction and caliper failed. |
| (2) | 1500 | 5 December | Schlumberger LDT/CNTG/NGT/GPIT/AMS; data good. |
| (3) | 1815 | 5 December | Schlumberger GST/ACT/CNTG/NGT/GPIT/AMS; two passes. Data excellent. |
| (4) | 0730 | 6 December | Schlumberger DIT/GR/CAL; repeat of Run 1. Data good. |
| (5) | 1045 | 6 December | Schlumberger DLL; data excellent. |
| (6) | 1300 | 6 December | USGS temperature log 1; good results, temperature higher toward top of hole. |
| (7) | 1630 | 6 December | LDGO BHTV; both tools failed. No data collected. |
| (8) | 0030 | 7 December | LDGO MCS; data good except for top 100 m of hole. |
| (9) | 0700 | 7 December | USGS magnetometer; data good. |
| (10) | 1600 | 7 December | UW magnetometer/magnetic susceptibility tool; magnetic data good, susceptibility data miscalibrated. |
| (11) | 2015 | 7 December | USGS magnetic susceptibility tool; data good. |
| (12) | 2315 | 7 December | LDGO MCS; repeat of Run 8. Good data over missing 100 m of hole. |
| (13) | 0300 | 8 December | USGS temperature log 2; good data; most of hole cooling since run 1. |
| (14) | 0630 | 8 December | WHOI VSP; partially successful. Logged bottom of hole, then hydraulic arm clamping problems on one tool, other tool did not work. |
| (15) | 1215 | 8 December | LDGO BHTV; good data. Centralizer bracket top-plates left in hole. |
| (16) | 2300 | 8 December | WHOI VSP; unsuccessful, both tools failed. |
| (17) | 0100 | 9 December | Schlumberger WST; shot 22 stations (about five shots each with water and airgun). |
| (18) | 0245 | 9 December | WHOI VSP; problems gone when tool set properly; 24 clampings at 15–25 m intervals. Good data. |
| | 2045 | 9 December | Pull out of hole. |
| Second pipe trip (packer in BHA) | | | |
| | 0145 | 10 December | Reentered hole. |
| (19) | 0345 | 10 December | Six successful packer sets at 778, 780, 954, 954, 1030, and 1120 mbrf. Slug and flow tests good. |
| | 2200 | 10 December | Pulled out of hole; time expired. |

[1] Start time refers to time logging tool left the rig floor. In the case of the packer experiment, this refers to time the first go-devil was seated in the packer. LDGO = Lamont-Doherty Geological Observatory; WHOI = Woods Hole Oceanographical Institute; BHTV = borehole televiewer. Logs are explained in appropriate sections (this chapter).

fore bringing the pipe to the surface at 2200 hr on 10 December. Data from the packer were excellent and showed that the hole was permeable in the upper part and very impermeable toward the bottom.

The ship departed Site 735 at 0730 hr on 11 December after retrieving the acoustic positioning beacon. Geophysical gear was streamed to determine the position of the hole in relation to the edge of the fracture-zone wall (see end of "Approach to Site 735" section, this chapter).

## LITHOSTRATIGRAPHY

Six lithologic units were identified at Site 735 (Fig. 5). The divisions between them are based upon primary igneous modal mineralogy, mineral composition, and degree and style of deformation. A summary of the downhole petrographic and deformational characteristics are included in Figures 6, 7, and 8.

### Unit I

Lithologic Unit I is a foliated metagabbro (0.0–0.2 mbsf in Hole 735A, 0.0–39.5 mbsf in Hole 735B; Cores 118-735B-1D through -11D). This unit consists of metagabbro with porphyroclastic to mylonitic textures. There is usually a well-developed foliation dipping at 25° to 35°. Rock types include poorly foliated metagabbro, porphyroclastic gabbro, mylonite, gabbroic gneiss, and augen gneiss. Samples range from very fresh metagabbro containing clinopyroxene and plagioclase porphyroclasts and neoblasts to amphibole plus plagioclase metagabbro. Both types include orange-red oxidized pseudomorphs after olivine and orthopyroxene. Amphibole- and sodic plagioclase-rich zones clearly crosscut the foliation in several sections, and the amphibole fills fractures that also cut the foliation, indicating that most of the amphibole formed after deformation.

The protolith for most of the metagabbros was a two-pyroxene gabbro or gabbronorite. Orthopyroxene porphyroclasts make up 1%–10% of several samples (Fig. 6). Olivine remnants occur in intervals, particularly in the lower part of the unit (Fig. 6). In some of the cores, mylonitic bands rich in iron-titanium oxides may have had an opaque-rich gabbro protolith, but no relict mineralogy was determined. Some of these oxide-rich zones are clearly secondary because the oxides fill fractures and pore spaces within the samples. The common occurrence of olivine from Core 118-735B-7R downward (from 27 mbsf) indicates a more magnesium protolith for the rocks. Lithologic Unit I is defined principally by metamorphic criteria because relict igneous textures are not preserved. All Unit I rocks share a common deformational history, even though there were probably several different protoliths.

### Unit II

Lithologic Unit II is an olivine-bearing and olivine gabbro (39.5–180.0 mbsf, Cores 118-735B-12R through -37R). The upper boundary of this unit is defined by an abrupt decrease in the

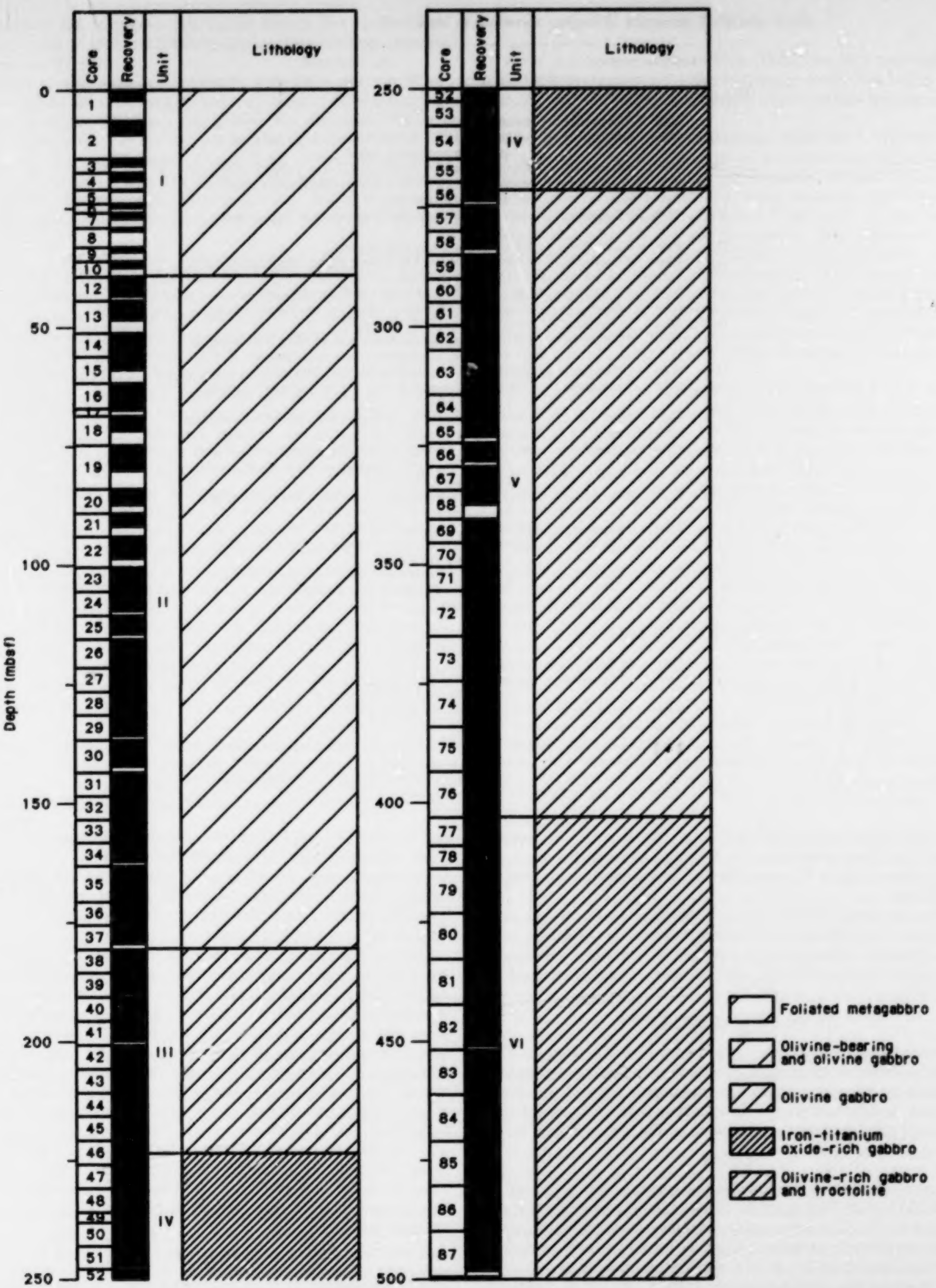

Figure 5. Basement lithostratigraphy of Hole 735B.

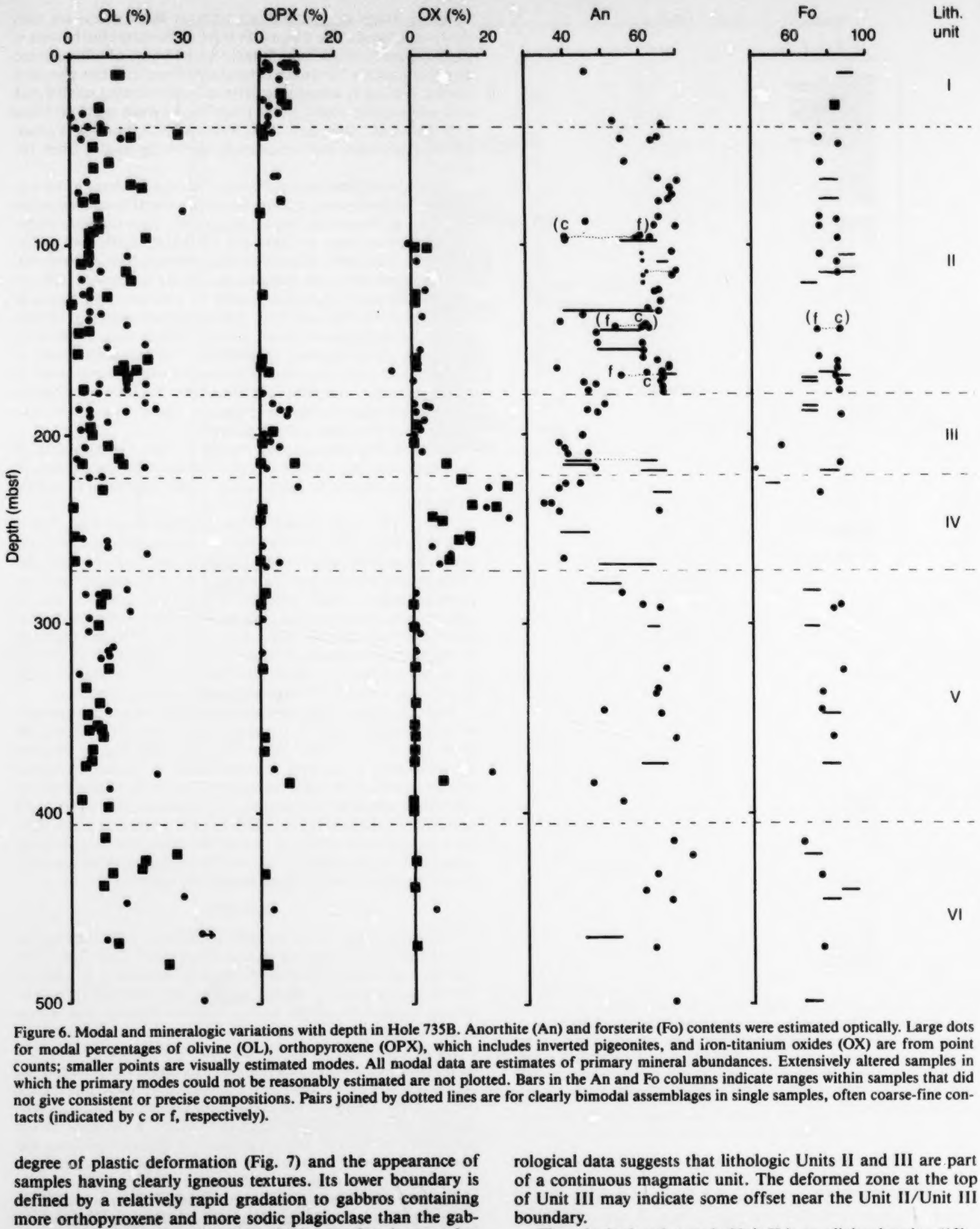

Figure 6. Modal and mineralogic variations with depth in Hole 735B. Anorthite (An) and forsterite (Fo) contents were estimated optically. Large dots for modal percentages of olivine (OL), orthopyroxene (OPX), which includes inverted pigeonites, and iron-titanium oxides (OX) are from point counts; smaller points are visually estimated modes. All modal data are estimates of primary mineral abundances. Extensively altered samples in which the primary modes could not be reasonably estimated are not plotted. Bars in the An and Fo columns indicate ranges within samples that did not give consistent or precise compositions. Pairs joined by dotted lines are for clearly bimodal assemblages in single samples, often coarse-fine contacts (indicated by c or f, respectively).

degree of plastic deformation (Fig. 7) and the appearance of samples having clearly igneous textures. Its lower boundary is defined by a relatively rapid gradation to gabbros containing more orthopyroxene and more sodic plagioclase than the gabbros in Unit II. The exact location of this boundary is somewhat arbitrary. Just below this boundary (in Core 118-735B-38R) are zones of slight deformation. The gradational nature of the petrological data suggests that lithologic Units II and III are part of a continuous magmatic unit. The deformed zone at the top of Unit III may indicate some offset near the Unit II/Unit III boundary.

The principal rock type in Unit II is an olivine-bearing (1%–5% olivine) or olivine (>5% olivine) gabbro. Most of the rocks are mesocumulates in which anhedral and subhedral granular

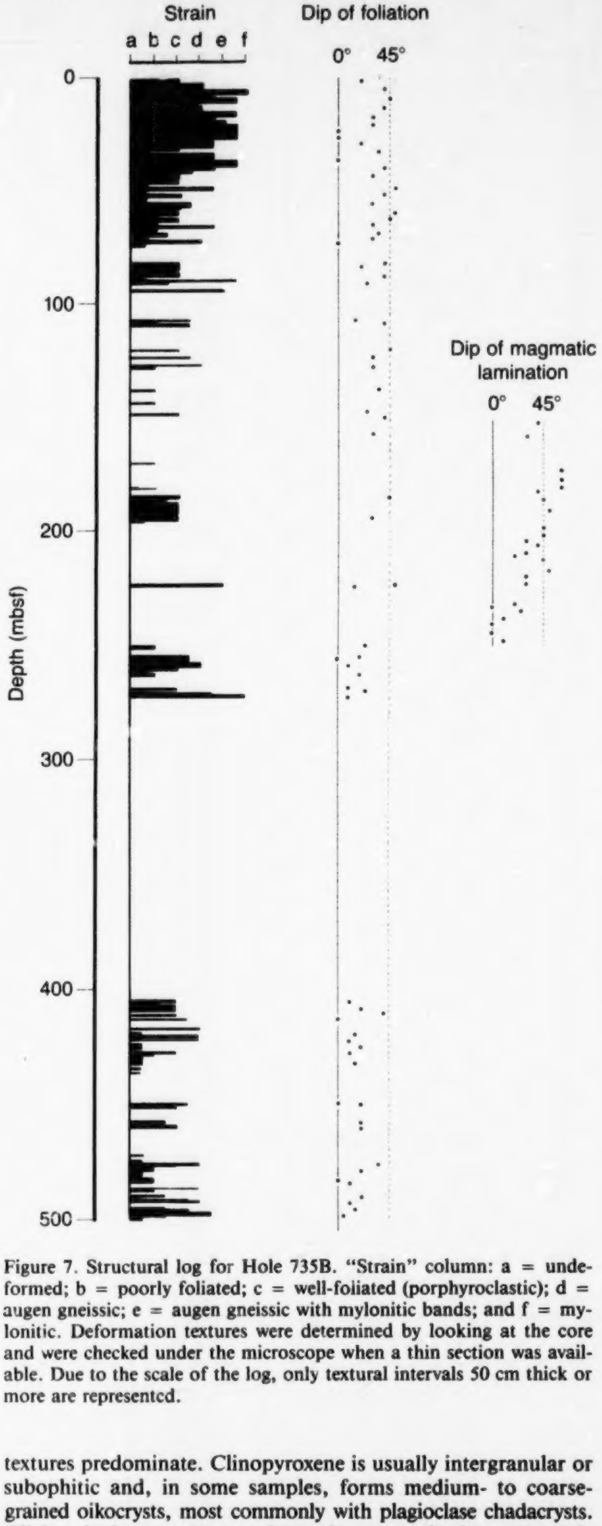

Figure 7. Structural log for Hole 735B. "Strain" column: a = undeformed; b = poorly foliated; c = well-foliated (porphyroclastic); d = augen gneissic; e = augen gneissic with mylonitic bands; and f = mylonitic. Deformation textures were determined by looking at the core and were checked under the microscope when a thin section was available. Due to the scale of the log, only textural intervals 50 cm thick or more are represented.

textures predominate. Clinopyroxene is usually intergranular or subophitic and, in some samples, forms medium- to coarse-grained oikocrysts, most commonly with plagioclase chadacrysts. Olivine chadacrysts are rare. Intervals commonly show magmatic layering, defined principally by size gradations from coarse- to medium- or fine-grained layers. The transitions between layers may be either sharp or gradational. Igneous laminations are only rarely developed. The magmatic layering is most clearly seen in the lower parts of the unit. Small pods or layers of microgabbro are common (see "Primary Petrography" section, this chapter). Modal layering is sometimes defined by alternating olivine-rich with olivine-poor zones. Short troctolitic intervals occur in Cores 118-735B-12R, -20R, and -26R. The magmatic layering is generally subhorizontal, but occasionally shows dip angles from 10° to 30°.

Thin layers (from one or two to a few centimeters) of iron-titantium oxide-bearing gabbro occur in several locations in the core (Fig. 8). Somewhat thicker intervals of iron-titanium oxide-bearing gabbro occur in Cores 118-735B-21R, -23R, -24R, -32R, and -34R. The rocks in these thicker intervals have igneous textures in which the oxide minerals are closely intergrown with pyroxenes. Inverted pigeonite occurs in pyroxene-rich layers in Cores 118-735B-23R and -35R. These intervals represent crystallization of significantly more evolved liquids than those from which the olivine gabbros crystallized. The few occurrences of iron-titanium oxides are usually associated with sheared zones in which secondary amphibole is abundant. We interpret these as zones of secondary oxide development. These oxide zones commonly have abundant sulfide minerals.

A basalt dike crosscuts the section in Core 118-735B-19R; it is aphyric and has chilled margins adjacent to the gabbro. A large microgabbro dike intrudes the olivine gabbro in Core 118-735B-23R.

The olivine-bearing and olivine gabbros range from 7.0 to 14.0 wt% MgO (see "Geochemistry" section, this chapter). Olivines are magnesium-rich ($Fo_{80}$, determined optically) and plagioclase compositions average about $An_{65}$. The plagioclase compositions within single samples or intervals, however, can be quite diverse, ranging from $An_{40}$ to $An_{65}$. This variation is often associated with adjacent coarse-fine intervals. This, and the range in MgO concentrations, indicate that lithologic Unit II formed in an environment in which there was frequent mixing of magmas having a range of magnesium and calcium contents.

Mylonitic and porphyroclastic intervals are not uncommon in Unit II, particularly in the upper part of the unit (Cores 118-735B-12R to 15R, -16R, -18R, -20R, and -22R; Fig. 7). Most of the remainder of the unit is undeformed or weakly brecciated and underwent only static metamorphism, with development of actinolitic amphibole. Fractures are common throughout the unit and are commonly filled with fibrous green actinolite. Olivine is ubiquitously altered in part to talc-tremolite-magnetite aggregates. Fracture surfaces between individual rock pieces commonly are coated with talc or actinolitic material.

### Unit III

Lithologic Unit III is an olivine gabbro, with intervals of iron-titanium oxide gabbro (180.0–224.0 mbsf, Core 118-735B-38R through Section 118-735B-46R-3 at 30 cm). This unit includes long sections of olivine gabbro, with intervals of iron-titanium oxide-rich gabbro having igneous textures and a pronounced igneous lamination. The oxide-rich zones occur in Cores 118-735B-38R, -42R, -43R, and -45R, and are associated with pyroxene-rich intervals (Fig. 6). The upper boundary of the unit is defined by the common occurrence of sodic plagioclase ($An_{40-45}$), an increase in the appearence and proportions of low-calcium pyroxene and iron-titanium oxides, a decrease in the proportion of olivine, the occurrence of iron-rich olivine, and the development of well-defined, steeply dipping primary igneous layering (Figs. 6 and 7). Although the unit is similar to lithologic Unit I in hand specimen, it is distinct petrographically.

The boundary between Units II and III coincides with a change in the chemical composition of the olivine gabbros ($>5\%$ olivine) from gabbros containing 12–13 wt% MgO to gabbros

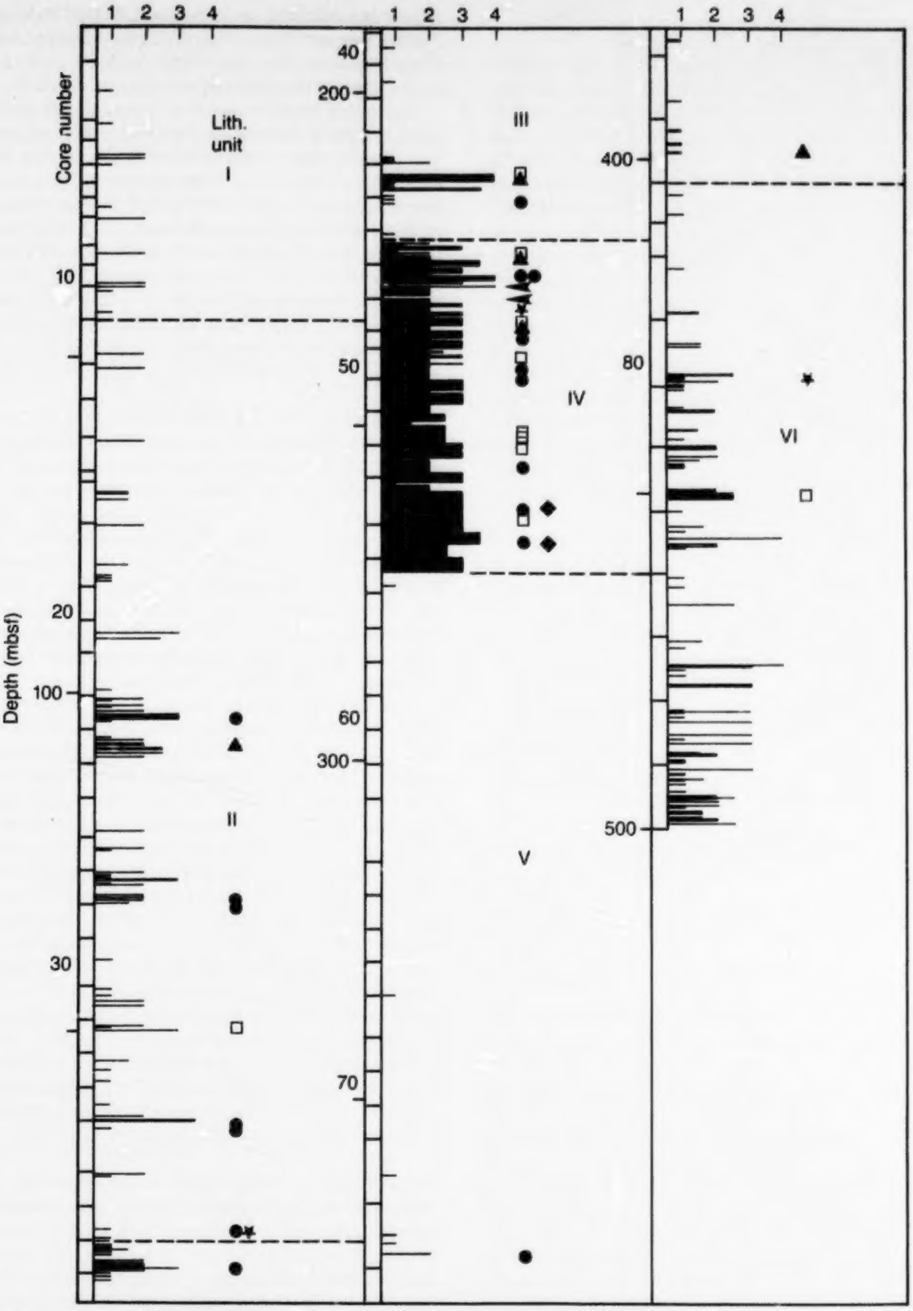

Figure 8. Relative abundance of opaque minerals vs. depth below seafloor. Relative abundances (numbers 1 to 4 on the horizontal scale) correspond to estimates (trace, common, abundant, very abundant) based on visual core descriptions. Symbols indicate different petrographic types based on thin section observations: solid circle = inverted pigeonite-bearing; solid triangle = orthopyroxene-bearing with fairly abundant clinopyroxene lamellae; square = orthopyroxene-bearing; solid star = iron-titanium oxide-bearing microgabbro with no calcium-poor pyroxene; solid diamond = apatite-bearing. Arrows indicate two occurrences of olivine gabbro in Unit IV.

containing 8–9 wt% MgO (see "Geochemistry" section, this chapter). There may be some interleaving of more- and less-evolved gabbro in the lower part of Unit III and the uppermost part of Unit IV, as seen by a few more calcic plagioclase compositions in those intervals (Fig. 6).

The igneous lamination in Unit III dips steeply in the upper part of the unit, but flattens until near-horizontal at the contact with Unit IV (Fig. 7). Mylonitic and foliated zones are common in Cores 118-735B-38R and -39R (Fig. 7). The contact between Units III and IV is marked by a 60-cm-thick mylonite zone.

### Unit IV

Lithologic Unit IV is an iron-titanium oxide-rich gabbro (224.0–272 mbsf, Section 118-735B-46R-3 at 30 cm through Section 118-735B-56R-3 at 90 cm). This unit represents an interval in which iron-titanium oxide-rich gabbro is the principal rock type (over 75% of recovered material). The contact with Unit III is a shear zone, but significant changes in mineralogy also occur between the two units. The gabbros of Unit IV commonly have more abundant opaque phases (10% or higher) and less olivine than the gabbros of Unit III. Like Unit III, the common plagioclase in these rocks is sodic ($An_{35-50}$), and some iron-rich olivines also occur (Fig. 6). The pronounced igneous lamination is subhorizontal in most of the unit (Fig. 7). The iron-titanium oxide-rich gabbros have subhedral granular textures, commonly with cumulus plagioclase and clinopyroxene. Olivine commonly is intergranular, and the oxide (a mixture of ilmenite and magnetite) forms intergranular to poikilitic masses enclosing plagioclase and clinopyroxene. Low-calcium pyroxene occurs in some samples and includes both primary orthopyroxene and inverted pigeonite. Olivine is normally as abundant, or slightly more so, than the low-calcium pyroxene. The gabbro is typically coarse- to very coarse-grained. Primary layering is well-defined by a distinct igneous lamination of clinopyroxene and plagioclase, coarse to medium or fine grain-size transitions, and occasional development of pyroxene- or plagioclase-rich bands. Large pyroxene and plagioclase crystals sometimes are elongated perpendicular to the layering (see "Primary Petrography" section, this chapter).

Olivine gabbro occurs infrequently in 20- to 100-cm-thick intervals. Mylonitic zones are uncommon and are concentrated in the upper and lower parts of the unit. A felsic intrusion breccia with a large (4 cm) trondjhemitic vein occurs in Sections 118-735B-53R-4 and 118-735B-54R-2.

The lower boundary of the unit is marked by a 2- to 3-m-thick layer of mylonitized oxide-rich gabbro. The mylonitic gabbro has a sharp lower contact with a brecciated olivine gabbro at the top of Unit V.

### Unit V

Lithologic Unit V is an olivine gabbro (272.0–403.5 mbsf, Section 118-735B-56R-3 at 90 cm through Core 118-735B-76R). The upper contact of this unit is marked by a brecciated zone below the mylonitized oxide-gabbro. Its lower boundary with Unit VI is defined by the appearance of a pervasive, weak to moderate deformation that persists through most of Unit VI (Fig. 7). It also marks the beginning of a zone characterized by the common occurrence of troctolites and olivine-rich gabbros. Petrologically, the lower boundary is gradational and, like the Unit II/Unit III transition, may be a zone of small offsets of a continuous magmatic section. Overall, Unit V is characterized by a marked lack of deformation. All of the rocks of Unit V are characterized by an abundance of olivine (5% or greater in nearly all samples) and a scarcity of oxides and low-calcium pyroxene (both present but only in trace amounts). Most of the samples are mesocumulates having subhedral granular to anhedral granular textures. Clinopyroxene is intergranular to ophitic and, in some cases, occurs as large oikocrysts. Primary layering is defined by coarse to fine grain-size changes and, less commonly, by lamination of the plagioclase. A troctolitic interval occurs in Sample 118-735B-63R-4, 35–43 cm, Piece 3C. There are a few plagioclase-rich intervals in the unit. This olivine gabbro more commonly has long (2–4 m) intervals of massive, medium- or coarse-grained rock than does the olivine gabbro of Unit II.

MgO ranges from 8 to 16 wt% but typically is between 10 and 12 wt% (see "Geochemistry" section, this volume). Plagioclase compositions are principally between $An_{60}$ and $An_{65}$, and olivine averages $Fo_{80}$ (Fig. 6). This unit apparently crystallized from a magma that was better buffered and experienced fewer mixing events than that which formed Unit II.

There are frequent zones of brecciation associated with felsic veins and the growth of epidote and albite. An oxide-rich interval occurs in Sample 118-735B-73R-4, 84–86 cm, Piece 2B, associated with a small shear zone and extensive amphibolitization of the clinopyroxene. Gabbro in this interval contains inverted pigeonite, which suggests a primary iron-rich composition. Near the lower boundary of Unit V in Section 118-735B-74R-6, there is a 50-cm-thick intrusion of microgabbro composed of orthopyroxene, iron-titanium oxide, and apatite. In general, however, Unit IV is remarkably free of iron-titanium oxide-rich zones, in contrast to the olivine gabbro of Unit II (Fig. 8).

### Unit VI

Lithologic Unit VI is an olivine-rich gabbro and troctolite (403.5–500.7 mbsf, Cores 118-735B-77R through -88N). This unit is an interval of olivine-rich (commonly >10%) gabbro having frequent layers and intrusions of troctolite (Fig. 6). Olivine-gabbro having mesocumulate texture is the principal rock type; it is similar to the olivine gabbro of Unit V except for the consistently higher modal proportions of olivine. Igneous layering is defined principally by size gradings, which are frequent and well-developed. Pyroxene oikocrysts have maximum linear dimensions up to 10 cm, and both clinopyroxene oikocrysts and large, cumulate plagioclase crystals are commonly oriented perpendicular to the igneous layering.

Interlayered with the gabbro are zones of troctolite and troctolitic gabbro. Troctolites occur in Cores 118-735B-77R, -79R, -83R, and -87R and include both olivine- and plagioclase-rich varieties. A coarse-grained olivine-rich troctolite occurs in Core 118-735B-83R, but the most common troctolite occurrence is as microgabbro dikes or layers that have granular textures. Chromium-spinel occurs in some coarse- and fine-grained troctolites.

Layers and lenses of olivine microgabbro with equigranular textures are also common. These microgabbros occur in Cores 118-735B-74R, -75R, -76R, and -77R. Iron-rich gabbros occur in Core 118-735B-77R. These evolved compositions are rare in the section. Other oxide-rich zones are associated with small shears and zones of extensive amphibolitization. The oxide is typically concentrated in thin zones at the margins of the shears. A trondjhemitic vein cuts the gabbro in Core 118-735B-79R.

Lithologic Unit VI has frequent intervals of plastic deformation (Fig. 7). Most of Cores 118-735B-84R through -87R is characterized by mylonitic to porphyroclastic textures. Foliated or mylonitic zones also occur in Cores 118-735B-77R, -78R, -79R, and -80R.

Gabbros in Cores 118-735B-79R through -87R contain an unusual pyroxene, which is pinkish-brown in hand specimen but is indistinguishable in thin section from clinopyroxenes higher in the section. From Core 118-735B-79R downward the rock also commonly contains a dull, emerald green pyroxene that typically has a subophitic or poikilitic texture enclosing plagioclase. These green pyroxenes are most commonly associated with the troctolitic zones. In hand specimen this pyroxene appears to be intergrown with or replaces the brown pyroxene. In the one thin section examined, it is a clear, optically continuous, green clinopyroxene, similar to a chromium diopside. The textures and occurrence of the pyroxenes are discussed in more detail in the "Primary Petrography" section (this chapter).

Units II and III and Units V and VI appear to record two relatively continuous magmatic sections, although there is evidence of minor offsets near each lithologic boundary. The Unit I/Unit II contact is defined by a change in deformation style and may or may not be a major tectonic boundary. The base of

Unit IV clearly is bounded by a major fault. Unit III appears to be chemically and petrographically transitional from the gabbro of Unit II to the iron-titanium oxide-rich gabbro of Unit IV. This unit may represent a magmatic transition, but there is a distinct mylonite zone at the top of Unit IV, and it is possible that the entire section is tectonically interleaved. There is, however, no question that small intervals of olivine gabbro occur in the oxide gabbro, and vice versa, which are clearly of magmatic origin. The contact between Units V and VI is likewise somewhat ambiguous. Unit VI is significantly more sheared than Unit V, and a large microgabbro intrusion occurs near the contact of the two. No clearly definable fault zone can be seen between the two, as with Units IV and V, but we were unable to define unambiguously the contact as magmatic.

## STRUCTURE AND DEFORMATION

### Introduction

The extent, manner, and intensity of deformation of the rocks drilled in Hole 735B vary considerably downhole. Although both plastic and brittle deformation occurred to varying degrees, there are relatively few open fractures and joints in the rocks recovered. For example, we measured the orientation of fractures and veins in 45 cores, mostly from the upper one-half of the hole and found 687 veins filled with amphibole and other metamorphic minerals and only 25 obvious open joints and fractures. The massive nature of the gabbro and the scarcity of open fractures were largely responsible for the exceptionally high recovery at this site. Nearly one-half the cracks and joint surfaces recorded were found in the upper 10 cores, which may have contributed to the overall lower recovery rates there. However, the lower recovery in the upper sections of the hole may also reflect the use of the mud motor, rather than of the rotary coring system.

About 30% of the gabbros in Hole 735B are plastically deformed, and these occur largely in three main intervals: 0–70, 250–272, and 405–500 mbsf (Fig. 7). Brittle deformation structures in the gabbros include numerous fractures filled with amphibole and result from extension contemporaneous with plastic deformation. These veins are scattered throughout the core, but their density is highest in the upper 220 m. Both deformed and undeformed veins are common. Well-developed igneous lamination, modal layering, and graded bedding were observed in the olivine gabbros and iron-titanium oxide gabbros of lithologic Units II, III, and IV (50–272 mbsf; Fig. 7); such features are also sporadically present in the olivine gabbros and troctolites in the lower portion of Unit VI.

### Plastic Deformation Structures

We distinguished five types of textures produced by increasing plastic deformation: (1) poorly foliated, (2) foliated, (3) well foliated or porphyroclastic, (4) augen gneissic, and (5) mylonitic.

In unfoliated or poorly foliated specimens, the foliation is either very faint, marked by the slight elongation of pyroxene in a plagioclase matrix, or not pervasive, with very thin shear zones (< 1 cm wide) crosscutting virtually undeformed gabbros. Foliated and well-foliated or porphyroclastic specimens are characterized by a pervasively shaped fabric of the mafic phases and by partial recrystallization of the plagioclase. Augen gneissic textures (Fig. 9) are defined by a clear and pervasive foliation. The plagioclase grains are extensively kinked and recrystallized, and the pyroxenes form rounded augen with tails of recrystallized grains and/or amphibole. Discrete mylonitic zones less than 0.5 cm wide are present. These rocks exhibit a marked banded appearance, defined by porphyroclastic layers and layers of gneissic material having stripes of alternating recrystallized mafic minerals and plagioclase. In the mylonitic gabbros (Fig. 9), the rounded pyroxene augen, and/or the clusters of recrystallized olivine grains, appear to float in an extremely fine-grained matrix. The grain size is locally so fine that the foliation is difficult to see.

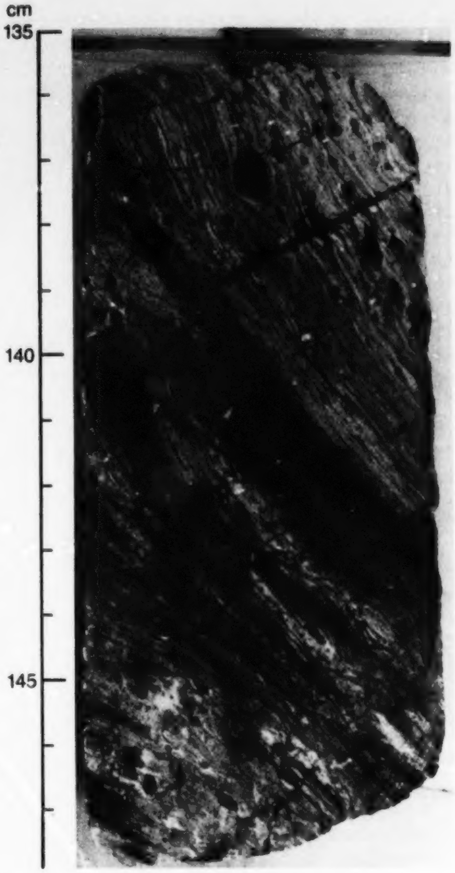

Figure 9. Deformed gabbro with augen gneissic (upper and lower ends of sample) and mylonitic (middle part of sample) textures (118-735B-2D-1, 135–148 cm, Piece 24).

Undeformed or poorly foliated gabbros commonly are juxtaposed directly with augen gneissic or mylonitic metagabbros (Figs. 10A and 10B). This reflects very high-strain gradients; the poorly foliated and well-foliated gabbros obviously experienced less total strain than the augen gneissic gabbros, which in turn are less strained than the mylonitic gabbros. In Figure 7, the deformation textures are used to estimate the relative strain intensities through the core. However, the relationship between the textural types and the strain is certainly far from linear. The shear strain accommodated by a 10-cm-thick mylonitic band may be greater than that accommodated by a 100-m-thick section of poorly foliated gabbro.

These textures mostly developed at high temperatures in the stability field of clinopyroxene plus brown hornblende ± olivine ± orthopyroxene (see "Metamorphism and Alteration" section, this chapter). In the well-foliated gabbros, intracrystalline deformation of the plagioclase porphyroclasts seems to have produced a good preferred orientation. This preferred orientation appears weaker in the augen gneissic and mylonitic gabbros, where the plagioclase porphyroclasts are almost completely re-

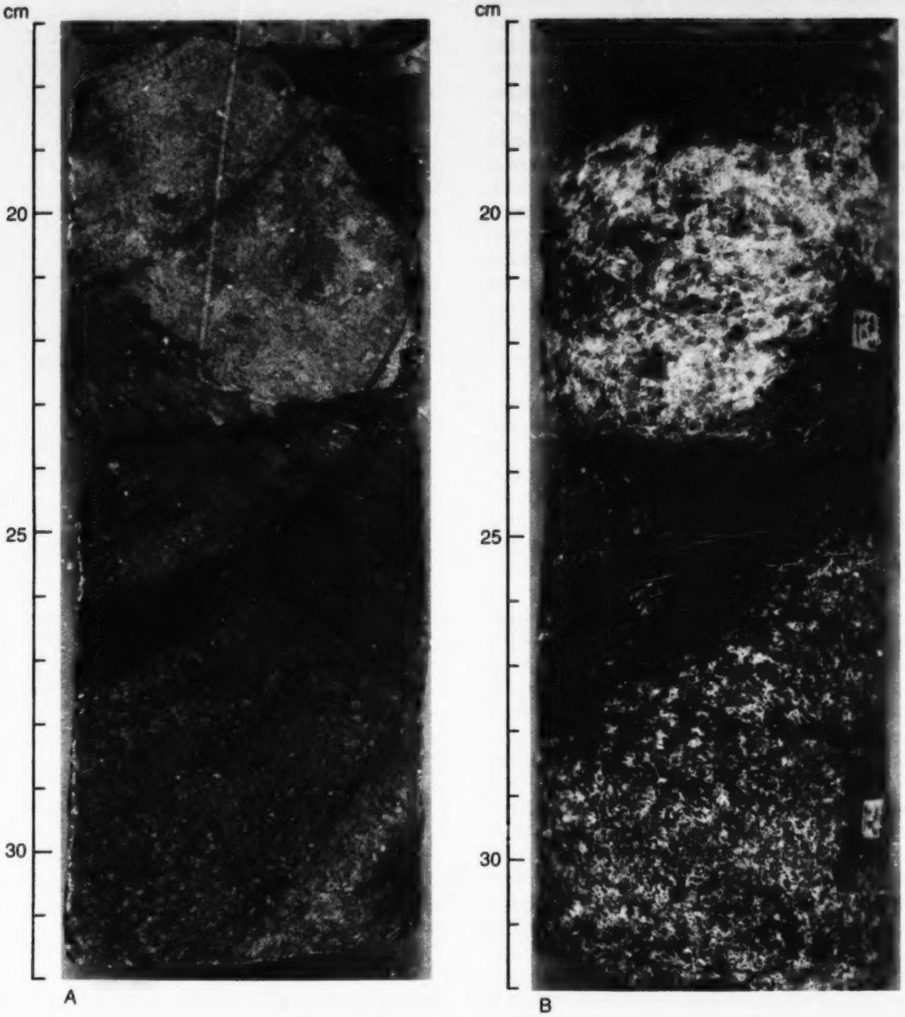

Figure 10. Lower limit of a deformation zone. A. View of split surface. B. View of cored surface. Clear-cut contact between a mylonitic gabbro and an undeformed gabbro with igneous lamination. The mylonitic gabbro contains up to 20% iron-titanium oxides. The igneous lamination, dipping about 20°, is visible on the cored surface (118-735B-46R-3, 17-32 cm, Pieces 2C and 2D).

crystallized to a mosaic of polygonal grains. The clinopyroxene is commonly kinked and partly recrystallized. In the most deformed gabbros, the clinopyroxene porphyroclasts, or augens, appear passively rotated in the fine-grained plagioclase matrix and develop tails of recrystallized grains elongated in the foliation. In the orthopyroxene, intracrystalline plastic deformation locally produces a preferred orientation of the (100) slip planes close to the foliation. But the dominant deformation mechanism in orthopyroxene seems to be kinking and fracturing. Recrystallization of orthopyroxene is only rarely observed (see "Metamorphism and Alteration" section, this chapter). The olivine is plastically deformed, and subgrain boundaries are frequent. The olivine appears to have a crystallographic-preferred orientation in some well-foliated gabbros. In the augen gneissic and mylonitic gabbros, however, recrystallization appears to supercede intracrystalline dislocation creep as the principal deformation mechanism, and the olivine is recrystallized to aggregates of polygonal grains having no apparent subgrain boundaries or preferred orientation. Overall, recrystallization or fracturing of the primary minerals is ubiquitous in the most strongly deformed gabbros. This suggests high differential stresses and strain rates during the deformation.

Shearing also occurred at presumably higher water/rock ratios and perhaps lower temperatures (see "Metamorphism and Alteration" section, this chapter) in the highly deformed upper 70 m of the hole (Fig. 7) and along steeply dipping amphibole veins and discrete shear zones in the rest of the core. The plagioclase and the brownish-green to green amphibole replacing the pyroxenes were kinked and recrystallized during this deformation.

Many of the high-strain zones cutting the gabbro show a large enrichment in iron-titanium oxides that sometimes exceed 10 or 20 vol%, with a sharp decrease at the boundary of the shear zone with undeformed gabbro (Figs. 10A and 10B). A common occurrence is a 1- or 2-cm-thick band of sheared or mylonitized, oxide-rich gabbro cutting an oxide-poor gabbro.

Overall, a strong association exists between deformation and ilmenite-magnetite enrichment throughout the section, with 0.2- to 10-cm-thick intervals of oxide-rich, plastically deformed metagabbro (1%-50% ilmenite and magnetite) occurring in lithologic Unit VI (below 400 mbsf; Fig. 7) and smaller zones occurring in Unit III (180-224 mbsf), interspersed with relatively undeformed and unaltered olivine gabbro zones. The paucity of oxides in the latter intervals is striking compared to the local enrichments in the adjacent metamorphosed and deformed gabbro. Although most of the plastically deformed zones in Hole 735B do not show such enrichment and much of the clearly magmatic ilmenite-magnetite gabbro in Unit IV (224-272 mbsf) is relatively undeformed, the zones of iron-oxide enrichment in Units III and VI commonly show a striking correlation among deformation, hydrothermal alteration of silicates to hornblende, and the presence of what appears to be secondary iron-titanium oxide. In these zones, the oxide is interstitial between deformed and recrystallized silicates. Local oxide-rich veins crosscut the primary igneous textures. In a number of cases, however, local shear zones a few centimeters thick show striking enrichment of iron-oxides, with little hydrothermal alteration of the silicates. This suggests that the passage of the fluids that precipitated the oxides through these shear zones took place at sufficiently low water pressure to preclude formation of the hydrous silicates (see discussion in "Metamorphism and Alteration" section, this chapter).

This association of intense plastic deformation with iron-titanium oxide enrichment might be due to localization of strain in previously formed oxide-rich zones, perhaps as a consequence of a rheological contrast between silicates and possibly more ductile oxides. Alternatively, it may be a result of channeling in the shear zones of hydrothermal fluids rich in dissolved oxides.

### Brittle Deformation Structures

The numerous hydrothermal veins are typically about 1 mm wide, but range from hairline to more than 1 cm across. Multiple generations of jointing and fracturing are indicated by the presence of up to four different vein mineral assemblages in the core, sometimes with crosscutting relationships. Throughout the core there is a large population of very small, scarcely noticeable, subhorizontal white veins or open fractures that crosscut the higher-temperature amphibole veins. These appear to have developed very late, either because of unloading during uplift of the gabbro massif to its present elevation or to cracking that accompanied the drilling. By far the most prominent veins are monomineralic green amphibole veins that range from less than 100 $\mu$m to more than 1 cm thick and that occur throughout the core (495 of 687 veins measured for orientation). At about 85 mbsf (Fig. 7), plagioclase plus amphibole veins appear and persist to the bottom of the hole. These make up 12% of the veins measured. At about the same level, pale green veins (amphibole plus talc? or smectite) first appear and continue intermittently to the bottom of the hole. Deeper in the hole and adjacent to hydrothermally altered brecciated zones, vein assemblages include sphene and epidote in addition to amphibole and plagioclase. Diopside plus plagioclase veins appear below 300 mbsf. At several intervals, also adjacent to hydrothermally altered breccia zones, sparse carbonate veins crosscut the high-temperature silicate veins. These carbonate veins appear linked to highly localized oxidative alteration (see "Metamorphism and Alteration" section, this chapter).

Vein and fracture population statistics were collected from most of the cores in the upper one-half of Hole 735 and for a number of cores lower in the section. We found veins and fractures most abundant in the core between 0 and about 220 mbsf. In the upper mylonitic and gneissic zone (0-90 mbsf), we measured 332 veins and fractures in 42.5 m of recovered gabbro, which gave a minimum fracture density of roughly eight veins per meter. Between 90 and 220 mbsf, we measured 333 veins and fractures in 62.2 m of core, which yielded a minimum of 5.3 veins and fractures per meter. The veins and fractures in this interval crosscut the gneissic foliation but are locally sheared. Below 220 mbsf, the number of veins and fractures in the core decreases precipitously to an average well below one vein per meter. At about 315 mbsf and down to about 350 mbsf, the density of veins and fractures increases slightly, in the vicinity of 1-m-thick zones of hydrothermally altered breccia. The veins crosscut the foliation and are generally undeformed, suggesting that they post-date the plastic deformation. However, the veins often do not cross zones of gneissic foliation or mylonite, which suggests that there they may have predated plastic deformation and were obliterated locally along zones of shear. It is also possible that the veins developed penecontemporaneously with this deformation because of brittle extension of the otherwise undeformed gabbro between the principal shear zones. Yet a third possible explanation is that the highly deformed gabbros were more resistant to brittle failure during the veining event than the surrounding poorly deformed gabbros. Locally, in the gneissic and mylonitic intervals, small amphibole veins orthogonal to the foliation crosscut stretched plagioclase augen; they represent extensional cracking and infilling penecontemporaneous with the plastic deformation. Numerous through-going amphibole veins in the same rocks are parallel to these cracks and are orthogonal to the foliation (Fig. 11), showing that cracking and vein filling related to the same basic regional stress field continued for some time after the end of the plastic deformation, possibly due to relaxation of the stored elastic strain.

Figure 12 is a histogram of the dips measured on 687 veins and fractures in 45 cores, mostly in the upper two-thirds of the hole. We excluded the set of subhorizontal white veins. Overall, most of the veins dip from 40° to 90°, with a strong peak between 60° and 65°, orthogonal to the prominent foliation, which averages 35° (Fig. 7). In general, conjugate vein sets are not visi-

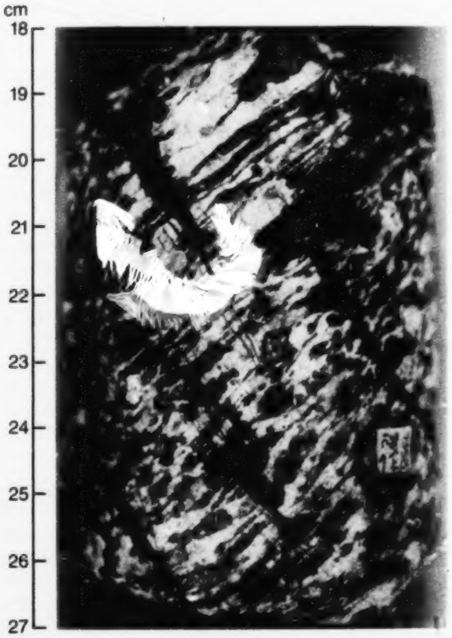

Figure 11. Amphibole veins perpendicular to the foliation in a well-foliated to augen gneissic gabbro (118-735B-85R-4, 18-27, Piece 1C).

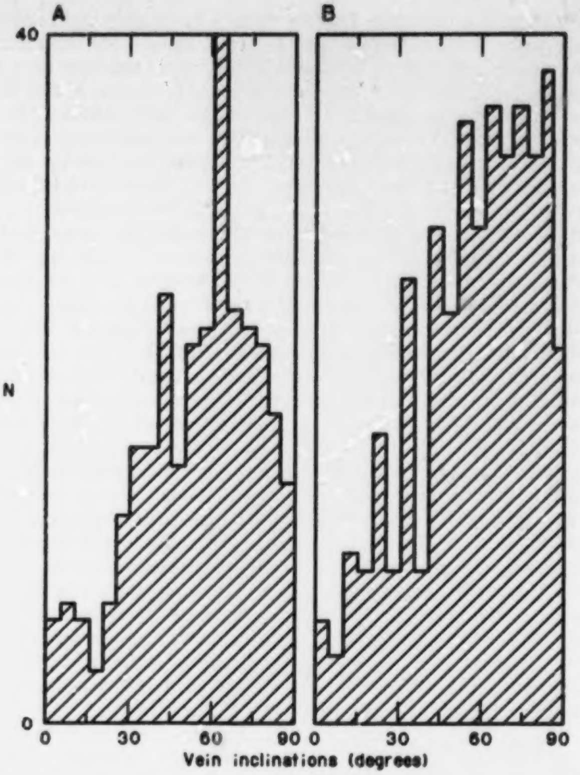

Figure 12. Histogram of the dips of the amphibole-bearing veins in Hole 735B. A. Cores 0-20. B. Cores 21-78.

ble in individual cores, and most veins, even those containing different mineral assemblages, all dip in the same direction. This suggests that the foliation suppressed the development of conjugate joints. Conjugate vein sets are evident in the more massive unfoliated gabbros.

Figure 12 clearly shows that the distribution of vein dips is skewed toward steeper inclinations. Interestingly, the peak distribution shifts to substantially steeper dips for veins measured below 90 mbsf (Core 118-735-21R), with the mean dip increasing as well. Unfortunately, foliations are poorly developed between 90 and 300 mbsf, which is the interval over which the majority of our vein data for the deeper section of the hole were obtained. However, the mean dip of the foliation decreases from about 35° in the upper part of the core, to about 30° below 250 mbsf (Fig. 7). This suggests that the stress field deeper in the hole was rotated with respect to that higher in the hole, and that the maximum principal stress was closer to vertical. Such a downward decrease in dip of foliation is also consistent with stacked listric normal faults, which flatten with depth as they pass downward into the underlying ductile zone.

### Cataclastic Deformation

Three separate major zones of autoclastic metagabbro breccia were drilled at 176-181, 273-275.5, and 328.5-330 mbsf. The uppermost zone coincides with the contact between lithologic Units II and III; the second lies just below the base of the mylonite separating the Unit IV magnetite-ilmenite gabbro from the underlying Unit V olivine gabbro; whereas the third such zone appears to lie within Unit V. In the former two cases, faults or lithological contacts possibly may have localized hydrothermal alteration. The base of the mylonite at the bottom of Unit IV shows the effects of the hydrothermal alteration, which is developed much more extensively in the brecciated gabbro below it. Thus, the hydrothermal alteration post-dates the plastic deformation in this zone. The breccia zones all appear structurally similar, although they contain somewhat different mineral assemblages. The lowermost zone is particularly well exposed in the core, beginning with an amphibole-rich vein that cuts upward into massive gabbro. Downward, the vein broadens to enclose angular fragments of the gabbro and its constituent minerals, which appear to be *in situ*. Hydrothermal epidote, quartz, and plagioclase occur in the cementing matrix. The vein disappears into disaggregated gabbro and mineral fragments that seem randomly arranged in a matrix of finer-grained fragments and hydrothermal minerals. The breccias show no evidence of plastic deformation, although considerable cataclasis and possibly crushing has occurred, which suggests that these breccias post-date the plastic deformation. These zones could represent hydrothermal upflow zones, perhaps the product of fluids hydrofracturing through the gabbro.

### Intrusive Contacts

A single basalt dike crosscuts gabbro in Sections 118-735B-23R-4 and 118-735B-23R-5 (100 mbsf). It consists of chemically normal mid-ocean ridge basalt (see "Geochemistry" section, this chapter). Both dike contacts were recovered in the core and dip at 50°. The dike has well-developed, chilled margins that consist of fine-grained to cryptocrystalline glassy basalt containing olivine and plagioclase microphenocrysts. The interior of the dike is substantially more altered and coarser grained and consists of fine-grained basalt having a greenish cast in hand specimen. Unfortunately, the particular pieces containing the contacts are unveined and unfoliated; thus, we could not determine if the basalt was crosscutting the foliation or the vein sets. The dike appears to be undeformed and at least 70 cm thick. The dip of the contacts, however, is close to that for the mean of the veins, which suggests that it could have been intruded under the same stress regime as the veins.

Trondjhemite veins composed largely of plagioclase and quartz were also found in the core. These veins crosscut gabbro having gneissic foliation in Cores 118-735B-53R and -54R (255 mbsf), where a small stockwork of trondjhemite veins occurs. Locally, the veins appear to have a trellised structure, with some apparent digestion of the wall rock indicated by a grayish color in the trondjhemite adjacent to the gabbro. The trondjhemite veins strike parallel to the gneissic structure, but dip 85°, 38°, and 45° from the dip of the foliation. Trondjhemites are generally believed to mark the last stage of magmatic evolution in ocean-ridge magma chambers. Given the evidence for local assimilation of the wall rock by the trondjhemite, the wall rocks must have been very hot and near their solidus at the time of intrusion. Thus, it is evident that the gneissic foliation must have developed near the region of magmatic activity at the ridge axis. This hypothesis is consistent with the high-temperature mineral assemblage found in the gneisses (see "Metamorphism and Alteration" section, this chapter).

### Igneous Lamination and Layering

Crystal layering is evident in a number of different forms throughout the section. The principal types include graded layering, phase layering, and modal layering. The most easily measured feature is an igneous lamination consisting of minerals that show a preferred tabular orientation, presumably as a result of crystal settling. The igneous lamination is marked by the shape fabric of euhedral plagioclase and clinopyroxene crystals. This lamination is well defined in the olivine gabbros and iron-titanium oxide gabbros of lithologic Units III and IV (see Fig. 6 and "Lithostratigraphy" section, this chapter). Lower in the section, well-developed phase layering occurs but is more difficult to measure. Plastic deformation textures may overprint the igneous lamination. When this is the case, the plastic foliation commonly crosscuts the igneous lamination at a high angle (Figs. 10A and 10B).

## Downhole Structural Evolution

### *Distribution of the Textural Types*

The log of the plastic deformation textures indicated a rough qualitative estimate of the downhole strain distribution (with a nonlinear scale; Fig. 7). Textures are well foliated to mylonitic from 0 to 40 mbsf. Deformation is then constrained to narrow, well-foliated to mylonitic zones down to about 250 mbsf. From 250 mbsf to the second brecciated zone at 273 mbsf, a pervasively deformed interval containing augen gneissic and mylonitic bands occurs. The gabbro is undeformed down to 405 mbsf. From 405 to 500.7 mbsf, the gabbro ranges from undeformed to augen gneissic having mylonitic bands too thin to plot on the log.

Overall, there are three main zones of plastic deformation, which suggests three major ductile faults. At least one of these faults separates two distinct petrologic units (the magnetite-ilmenite gabbro of Unit IV and the olivine gabbro of Unit V). In addition, a 60-cm-thick zone of augen gneissic gabbro having mylonitic bands occurs at the bottom of Unit III at 224 mbsf (Fig. 7); this could also be a ductile fault.

Igneous laminations and occasional igneous graded or modal layering are consistently present from 170 mbsf to the brecciated zone at 273 mbsf (Fig. 7). The laminations decrease in dip downhole from 60° at 170 mbsf to 0°-5° at 240 mbsf. Below this depth, the dip stabilizes and remains subhorizontal down to 250 mbsf. The zone of intense shear (about 60 cm of mylonitic and gneissic gabbro) at the Unit III/Unit IV boundary (223 mbsf) cuts the igneous lamination (Fig. 10B) without deflecting or otherwise disturbing it. This indicates that, at least here, the deformation post-dated the total solidification of the gabbro (Fig. 7).

## Dip of the Foliation

The foliation dips 0° to 60° and averages about 35° in the upper portion of the hole and about 20° near its bottom (Fig. 7). There are significant deviations from this overall pattern downhole. For example, foliations in the interval between 24 and 26 mbsf are subhorizontal, and in the interval at 400-435 mbsf the gabbros are cut by mylonitic shear zones a few centimeters thick that dip 50° to 70°. The lineations produced by mineral elongations, when visible in the cored section, are usually downdip, indicating normal or reverse faulting, rather than strike-slip motion. The steeper dipping shear zones below 400 mbsf have a sense of shear that suggests normal faults, which may post-date the low-angle fault planes associated with the general foliation.

# PRIMARY PETROGRAPHY

A variety of igneous and meta-igneous rocks were recovered at Site 735. These include olivine-bearing and olivine gabbros, two-pyroxene gabbros, iron-titanium oxide-rich gabbros, troctolites, microgabbros, and rare basalts and trondjhemites. The two-pyroxene gabbros appear principally as porphyroclastic rocks in lithologic Unit I, along with metamorphosed olivine gabbros. Olivine and olivine-bearing gabbros are the principal constituent of Units II, III, V, and VI. Iron-titanium oxide gabbros are the dominant lithology in Unit IV but also occur in thin intervals in Units II, III, and VI. Troctolites are most abundant in Unit VI, but are found rarely in Units II and V.

## Porphyroclastic Gabbro

There are no igneous textures preserved in any of the porphyroclastic and mylonitic gabbros that make up Unit I from Holes 735A and 735B. Textures range from weakly foliated to mylonitic but are predominately porphyroclastic. Relict plagioclase, orthopyroxene, clinopyroxene, and iron-titanium oxides occur as porphyroclasts in a recrystallized matrix dominated by plagioclase. The plagioclase porphyroclasts are undulose, elongate augen, ranging from 4 to 10 mm in size. They make up from 5% to 30% of the rock; initial plagioclase abundances are estimated to have been 50% to 60%. Compositions are estimated optically to be between $An_{40}$ and $An_{60}$. Clinopyroxene occurs as 1- to 4-mm-wide augen, which now make up 2% to 15% of the rock but originally composed 30% to 50%. Orthopyroxene augen are 6 to 7 mm in size and make up 0% to 4% of the samples studied; original orthopyroxene abundances are estimated to have been from 0% to 10%. The pyroxene augen are bent and sometimes fractured. The clinopyroxene grains commonly have small patches and rims of brown amphibole. Olivine grains, 0.1 to 5 mm in diameter, occur in samples from Cores 118-735B-2D and 118-735B-6D through 118-735B-11D in abundances from 0% to 4%. We believe that the olivine composed up to 12% of the original rock. Orthopyroxene and olivine are found together in Sample 118-735B-10D-1, 24-26 cm, Piece 6A, and are inferred to have coexisted in one or two other samples. Small grains of iron-titanium oxide make up 2% to 3% of some samples; in rare cases, it may be as much as 23%. We believe that some of this oxide is primary, particularly in the orthopyroxene-bearing samples; however, much of it may be secondary because it (1) fills fractures perpendicular to the foliation, (2) occurs preferentially in porous portions of the rock, and (3) is sometimes associated with post-deformational development of green amphibole.

The olivine-bearing porphyroclastic gabbros are more common than the orthopyroxene-bearing gabbros from Core 118-735B-7D downward, although orthopyroxene-bearing gabbros do occur in this interval. This increase in olivine is reflected in more magnesian bulk-rock compositions, and probably indicates the occurrence of at least two protoliths for the porphyroclastic gabbros: olivine-bearing gabbro such as that found in Unit II and two-pyroxene gabbro or noritic gabbro. The latter is most common in Cores 118-735B-1D to -6D, and the former is the principal protolith in Cores 118-735B-7D to -10D.

## Olivine-Bearing and Olivine Gabbros

Olivine-bearing (<5% modal olivine) and olivine (>5% modal olivine) gabbros are the most abundant rock types recovered from Hole 735B. They are the main rock types in lithologic Units II, III, V, and VI. Their primary mineralogy, estimated by point counting—2000 points on 5 × 8 cm thin sections or 1000-1500 points on standard thin sections—consists of olivine (0%-25%), plagioclase (40%-70%), clinopyroxene (30%-50%), orthopyroxene (generally in trace amounts but up to 3%), and trace amounts of opaques, primary brown amphibole, and sulfides (see Table 3). Modal proportions in thin section vary considerably (Fig. 13), which partly reflects modal and phase layering within the intrusion(s) (see "Textural Variations" section, this chapter) and partly reflects the irregular distribution of crystals in coarse-grained rocks. The average grain size varies from fine (<1 mm) to very coarse (approximately 10 mm) and varies systematically within normally graded units (discussed in more detail in "Textural Variations" section, this chapter). Based on optical determinations, olivine compositions range from $Fo_{65}$ to $Fo_{85}$, with an average of $Fo_{80}$, and plagioclase compositions range from $An_{55}$ to $An_{72}$, with an average of $An_{65}$.

**Table 3. Mineral modes determined by point counting.**

| Core/section: | 118-735B-1D-1 | 118-735B-1D-1 | 118-735B-2D-2 | 118-735B-7D-1 | 118-735B-10D-2 |
|---|---|---|---|---|---|
| Interval (cm): | 78-82 | 117-120 | 116-120 | 74-76 | 18-20 |
| Rock type[1]: | 1,9 | 1,9 | 2,9 | 2,9 | 2,9 |
| *Primary minerals* | | | | | |
| Olivine | | | 3.7 | | 4.5 |
| Plagioclase | 30.9 | 23.0 | 55.1 | 8.6 | 19.8 |
| Clinopyroxene | 13.0 | 2.2 | 10.7 | 15.0 | 27.9 |
| Low-Ca pyroxene | | | | | |
| Opaques | | 3.3 | | | |
| *Secondary minerals* | | | | | |
| Clay minerals | 10.1 | | | tr | |
| Carbonate | tr | | | 1.0 | |
| Chlorite | | | 1.4 | | tr |
| Brown amphibole | 15.6 | 21.5 | 8.6 | 4.0 | |
| Actinolite | 5.9 | 8.6 | 0.6 | 21.8 | 10.3 |
| Tremolite | 11.3 | | 3.2 | 10.4 | 2.1 |
| Magnetite | 4.4 | | 0.8 | 0.5 | 1.3 |
| Talc | | | 1.7 | | |
| Plagioclase (neoblasts) | 8.8 | 41.1 | 13.0 | 38.5 | 24.6 |
| Clinopyroxene (neoblasts) | | | 0.4 | | 7.8 |
| Orthopyroxene (exsolution) | | | | | 0.4 |
| Other | | | 0.8 | 0.2 | 1.3 |

Modes are based on point counts of greater than 500 points.

[1] Key to rock types: (1) gabbro, (2) olivine gabbro, (3) Fe-Ti gabbro, (4) norite, (5) troctolite, (6) microgabbro, (7) basalt, (8) altered sample, (9) deformed and/or metamorphosed sample, (10) sample including a contact between two rock types or distinctive textures.

**Table 3 (continued).**

| Core/section: | 118-735B-19R-3 | 118-735B-19R-5 | 118-735B-20R-2 | 118-735B-21R-2 | 118-735B-21R-2 |
|---|---|---|---|---|---|
| Interval (cm): | 73-75 | 47-50 | 54-56 | 53-56 | 57-63 |
| Rock Type[1]: | 2,8 | 1,9 | 2 | 2 | 1 |
| *Primary minerals* | | | | | |
| Olivine | 2.8 | | 6.1 | 3.0 | 1.6 |
| Plagioclase | 40.0 | 10.0 | 61.2 | 51.9 | 64.5 |
| Clinopyroxene | 7.9 | 9.1 | 30.7 | 29.6 | 25.7 |
| Low-Ca pyroxene | | 4.4 | | | |
| Opaques | | | | | |
| *Secondary minerals* | | | | | |
| Clay minerals | 3.0 | 3.0 | | | |
| Carbonate | | | | | |
| Chlorite | 0.2 | | 0.1 | 0.4 | |
| Brown amphibole | | 1.1 | 0.7 | | 0.5 |
| Actinolite | 27.0 | 15.2 | 0.1 | 3.9 | 4.6 |
| Tremolite | 2.0 | | 0.2 | 1.5 | 1.8 |
| Magnetite | 1.0 | 1.8 | 0.1 | 0.1 | 0.1 |
| Talc | 0.4 | | 0.7 | 0.7 | 0.9 |
| Plagioclase (neoblasts) | 14.5 | 52.0 | | 8.6 | |
| Clinopyroxene (neoblasts) | | 3.4 | | 0.3 | |
| Orthopyroxene (exsolution) | | | 0.1 | | |
| Other | | | | | |

Typically, the gabbros and olivine gabbros are massive and have poorly defined layering and localized deformation structures. Near shear zones, porphyroclastic and mylonitic textures are common, and more than 50% of the rock has been recrystallized, thus obscuring primary grain sizes and shapes (see "Deformation and Structure" section, this chapter). In most of these rocks, however, the amount of recrystallization is limited to less than 5%, and the only evidence of strain is microscopic, including nearly ubiquitous kink banding in olivine and bent and/or dislocated twin lamellae in plagioclase. The degree of alteration varies from negligible to almost 50% and generally decreases downhole (Table 3). The types of alteration are discussed in detail in the "Metamorphism and Alteration" section, this chapter.

On the basis of primary textures, the gabbros and olivine gabbros can be subdivided into three groups: (1) poikilitic gabbro (Fig. 14), characterized by clinopyroxene oikocrysts that enclose or partially enclose plagioclase and sometimes olivine; (2)

**Table 3 (continued).**

| Core/section: | 118-735B-13R-2 | 118-735B-14R-4 | 118-735B-15R-3 | 118-735B-16R-5 | 118-735B-18R-2 |
|---|---|---|---|---|---|
| Interval (cm): | 55–58 | 22–25 | 92–96 | 47–51 | 143–146 |
| Rock Type[1]: | 2,9 | 2,9 | 1 | 6 | 2,8 |
| *Primary minerals* | | | | | |
| Olivine | 2.0 | 6.8 | 0.6 | 10.9 | 1.2 |
| Plagioclase | 41.0 | 11.8 | 23.5 | 52.5 | 52.2 |
| Clinopyroxene | 18.9 | 10.5 | 19.8 | 25.4 | 25.2 |
| Low-Ca pyroxene | | | | | |
| Opaques | | | | | |
| *Secondary minerals* | | | | | |
| Clay minerals | | 2.2 | 1.3 | 2.0 | |
| Carbonate | | | | tr | 0.2 |
| Chlorite | 2.4 | 0.8 | 0.1 | | 4.6 |
| Brown amphibole | 0.2 | 2.5 | 6.5 | 1.8 | |
| Actinolite | 4.6 | 5.2 | 19.2 | 2.8 | 6.2 |
| Tremolite | 2.6 | tr | 2.1 | | 6.2 |
| Magnetite | 0.1 | 1.2 | 2.4 | 0.1 | 2.6 |
| Talc | 0.3 | 2.0 | 1.1 | 4.3 | 1.6 |
| Plagioclase (neoblasts) | 27.3 | 51.3 | 22.9 | | |
| Clinopyroxene (neoblasts) | 0.6 | 4.2 | | | |
| Orthopyroxene (exsolution) | | 0.7 | | 0.2 | |
| Other | | | | | |

**Table 3 (continued).**

| Core/section: | 118-735B-22R-2 | 118-735B-22R-2 | 118-735B-22R-3 | 118-735B-23R-2 | 118-735B-23R-3 |
|---|---|---|---|---|---|
| Interval (cm): | 86–91 | 110–115 | 116–120 | 34–36 | 34–37 |
| Rock Type[1]: | 2 | 2,8 | 2,8 | 2 | 3 |
| *Primary minerals* | | | | | |
| Olivine | 17.8 | 0.3 | 0.4 | 3.7 | |
| Plagioclase | 32.6 | 52.6 | 40.0 | 53.2 | 20.0 |
| Clinopyroxene | 40.7 | 10.8 | 14.4 | 33.8 | 45.7 |
| Low-Ca pyroxene | | | | | 6.4 |
| Opaques | | | | | 15.0 |
| *Secondary minerals* | | | | | |
| Clay minerals | 0.3 | 1.7 | 3.0 | | |
| Carbonate | | | | tr | |
| Chlorite | tr | 1.7 | 2.0 | 1.2 | tr |
| Brown amphibole | 1.2 | tr | tr | | 6.6 |
| Actinolite | 3.5 | 29.1 | 33.9 | 6.3 | 6.3 |
| Tremolite | 0.5 | 2.4 | 1.5 | 1.4 | |
| Magnetite | 1.5 | 0.5 | 1.0 | 0.2 | |
| Talc | 1.2 | 0.1 | | 0.2 | |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | tr | | | | |
| Other | | 0.1 | | | |

granular gabbro (Fig. 15), characterized by tabular or prismatic plagioclase, subhedral clinopyroxene, and anhedral to subhedral olivine; and (3) equigranular microgabbro, which is distinctly finer grained (0.5–1.5 mm) than the main gabbro units. Use of the term microgabbro follows that of MacKenzie et al. (1982), who applied it to the fine-grained marginal facies of the Skaergaard intrusion.

Poikilitic gabbro is the most common type. These rocks are medium- to coarse-grained and contain clinopyroxene oikocrysts ranging in size from 2 mm to 10 cm. In many places, the oikocrysts are elongated in a subvertical direction (see "Textural Variations" section, this chapter). The pyroxene oikocrysts enclose chadacrysts of euhedral plagioclase and olivine. In rare instances, chadacrysts of olivine and plagioclase are intergrown and surrounded by clinopyroxene, indicating that olivine and plagioclase crystallized together prior to the crystallization of clinopyroxene. Granular gabbros are also medium- to coarse-grained. They are characteristic of the bottom part of size-

**Table 3 (continued).**

| Core/section: | 118-735B-23R-4 | 118-735B-24R-4 | 118-735B-25R-3 | 118-735B-26R-1 | 118-735B-26R-1 |
|---|---|---|---|---|---|
| Interval (cm): | 120–122 | 26–28 | 144–146 | 135–138 | 135–138 |
| Rock Type$^1$: | 7 | 1 | 2 | 6,10 | 2,10 |
| *Primary minerals* | | | | | |
| Olivine | | 1.1 | 9.4 | 3.7 | 8.0 |
| Plagioclase | 51.0 | 51.1 | 49.6 | 49.8 | 34.5 |
| Clinopyroxene | 24.1 | 18.9 | 26.4 | 14.8 | 30.9 |
| Low-Ca pyroxene | | | | | tr |
| Opaques | 3.3 | | tr | | |
| *Secondary minerals* | | | | | |
| Clay minerals | 16.0 | 3.0 | 0.3 | 0.3 | 0.8 |
| Carbonate | | | | | |
| Chlorite | | tr | | | |
| Brown amphibole | | tr | tr | 3.7 | 0.8 |
| Actinolite | | 23.9 | 3.3 | 14.6 | 12.7 |
| Tremolite | | 0.6 | 5.1 | 3.1 | 3.6 |
| Magnetite | | 0.5 | 0.2 | 3.9 | 2.2 |
| Talc | 5.3 | 0.3 | 5.6 | 5.4 | 6.2 |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | | |
| Other | | | | | |

**Table 3 (continued).**

| Core/section: | 118-735B-34R-4 | 118-735B-35R-1 | 118-735B-35R-4 | 118-735B-36R-3 | 118-735B-36R-3 |
|---|---|---|---|---|---|
| Interval (cm): | 8–12 | 29–31 | 43–46 | 28–34 | 28–34 |
| Rock Type$^1$: | 3 | 2 | 2 | 1,10 | 2,10 |
| *Primary minerals* | | | | | |
| Olivine | 0.7 | 5.7 | 8.6 | | 0.6 |
| Plagioclase | 42.3 | 56.0 | 49.0 | 52.4 | 59.3 |
| Clinopyroxene | 32.2 | 21.8 | 24.8 | 41.2 | 25.4 |
| Low-Ca pyroxene | | | | | |
| Opaques | 20.8 | | tr | | |
| *Secondary minerals* | | | | | |
| Clay minerals | 1.6 | | 0.1 | | |
| Carbonate | | | | | |
| Chlorite | 0.1 | 0.8 | 0.5 | | |
| Brown amphibole | 0.2 | 0.1 | | 1.5 | 2.6 |
| Actinolite | 0.6 | 9.2 | 9.0 | 4.8 | 8.2 |
| Tremolite | | 6.2 | 6.7 | | 0.5 |
| Magnetite | | 0.1 | 0.7 | | 2.5 |
| Talc | | | | | |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | 1.2 | | | | |
| Other | | | 0.6 | | |

graded units and sometimes form 1- to 5-cm-thick monomineralic or bimineralic layers (see "Textural Variations" section, this chapter). Olivine microgabbros occur sporadically as isolated pods or intrusive dikes or sills in Cores 118-735B-16R to 118-735B-40R (Fig. 16). Modal proportions determined in two microgabbros, one from Core 118-735B-16R and one from Core 118-735B-26R, are almost identical (Table 3): the average being 19% olivine, 53% plagioclase, and 28% clinopyroxene. Microgabbros of other lithologies, e.g., troctolite and iron-titanium oxide gabbro, occur elsewhere.

Crystals in the poikilitic and granular gabbros exhibit a variety of complex intergrowths. These include penetrative intergrowths between multiple clinopyroxene grains as well as between clinopyroxene and plagioclase grains. In extreme examples, blebby lamellae enclosed in one grain are optically continuous with an entire neighboring crystal. Another type of intergrowth is exhibited by vermicular (wormy) lamellae in clinopyroxene. These occur in pristine unaltered samples, sometimes appearing in only one side of a twinned crystal. They also occur in altered samples where clinopyroxene and amphibole form symplectic intergrowths at the margins of clinopyroxene grains. In the latter case, alteration of clinopyroxene appears to be controlled by crystal structure.

Textural relationships in thin sections and geochemical data (low abundances of incompatible elements, see "Geochemistry" section, this chapter) indicate that the olivine and olivine-

Table 3 (continued).

| Core/section:<br>Interval (cm):<br>Rock Type[1]: | 118-735B-28R-3<br>63-69<br>4 | 118-735B-31R-2<br>40-45<br>2 | 118-735B-33R-3<br>85-89<br>1 | 118-735B-34R-1<br>103-105<br>2 | 118-735B-34R-2<br>18-22<br>2 |
|---|---|---|---|---|---|
| *Primary minerals* | | | | | |
| Olivine | 0.1 | 1.8 | 0.7 | 11.7 | 10.0 |
| Plagioclase | 58.4 | 53.3 | 67.0 | 47.6 | 61.7 |
| Clinopyroxene | 2.0 | 36.4 | 24.9 | 25.7 | 21.4 |
| Low-Ca pyroxene | 29.9 | | | | |
| Opaques | 0.4 | | | tr | 0.1 |
| *Secondary minerals* | | | | | |
| Clay minerals | 0.4 | 0.2 | | 1.6 | 0.5 |
| Carbonate | | tr | | 0.1 | |
| Chlorite | | 0.3 | 1.4 | 0.3 | 0.9 |
| Brown amphibole | 2.8 | | tr | 0.1 | 0.1 |
| Actinolite | tr | 4.2 | 4.5 | 2.8 | 0.5 |
| Tremolite | 5.1 | 3.2 | 1.4 | 3.8 | 2.4 |
| Magnetite | | 0.1 | 0.1 | 1.0 | |
| Talc | | 0.4 | | 5.1 | 2.3 |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | 0.2 | 0.1 |
| Other | 0.9 | | | | |

Table 3 (continued).

| Core/section:<br>Interval (cm):<br>Rock Type[1]: | 118-735B-37R-1<br>11-13<br>1 | 118-735B-38R-2<br>78-84<br>2 | 118-735B-40R-5<br>13-15<br>1 | 118-735B-41R-4<br>20-27<br>2 | 118-735B-42R-2<br>119-121<br>2 |
|---|---|---|---|---|---|
| *Primary minerals* | | | | | |
| Olivine | 0.9 | 22.6 | 3.1 | 3.4 | 8.1 |
| Plagioclase | 44.0 | 30.8 | 57.6 | 56.0 | 77.3 |
| Clinopyroxene | 23.4 | 37.2 | 35.2 | 27.8 | 8.5 |
| Low-Ca pyroxene | | tr | | 1.9 | |
| Ilmenite | | 0.2 | 0.7 | 0.4 | 1.0 |
| *Secondary minerals* | | | | | |
| Clay minerals | 0.1 | | 0.7 | 1.0 | |
| Carbonate | | | | | |
| Chlorite | 0.8 | 1.0 | | 0.6 | 1.1 |
| Brown amphibole | 1.7 | | 1.1 | tr | tr |
| Actinolite | 18.2 | 2.3 | 0.3 | 6.9 | 1.8 |
| Tremolite | 0.2 | 3.3 | | 0.8 | 0.4 |
| Magnetite | 0.7 | 1.0 | 0.7 | 0.2 | 0.9 |
| Talc | | | | | 0.4 |
| Plagioclase (neoblasts) | 10.0 | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | | tr |
| Other | | 1.6 | | | |

bearing gabbros are cumulates, i.e., they represent crystal concentrates formed during magmatic crystallization. They may form by *in-situ* crystallization on the walls, floor, or roof of a magma chamber, as well as by crystal sorting due to crystal/liquid density differences. Olivine, plagioclase, and clinopyroxene are the cumulus phases in the olivine gabbros. Intercumulus phases include overgrowths on cumulus phases, such as suggested by concentric, progressive extinction of plagioclase rims, and phases restricted to interstitial areas, such as iron-titanium oxides, sulfides, orthopyroxene, and primary brown amphibole. In some cases, the pore spaces between cumulus crystals are filled with symplectic intergrowths of orthopyroxene and iron-titanium oxide. Intercumulus phases represent the crystallization products of liquid trapped in the pore space of accumulated crystals. Based on petrographic and geochemical data, the amount of crystallized trapped liquid in the olivine gabbros was 5% to 20%, which makes these gabbros adcumulates and mesocumulates.

## Troctolites

The troctolites (olivine and plagioclase-rich gabbros) from Hole 735B fall into two categories: (1) medium-grained poikilitic and (2) fine-grained equigranular. The poikilitic variety is characterized by oikocrystic olivine enclosing plagioclase or by oikocrystic plagioclase enclosing olivine and contains on average 43% olivine (1-6 mm), 53% plagioclase (1-10 mm), 3% cli-

**Table 3 (continued).**

| Core/section: | 118-735B-44R-3 | 118-735B-45R-1 | 118-735B-45R-1 | 118-735B-46R-4 | 118-735B-47R-4 |
|---|---|---|---|---|---|
| Interval (cm): | 78–81 | 48–51 | 48–51 | 109–113 | 80–86 |
| Rock Type[1]: | 2 | 2,10 | 3,10 | 3 | 2 |
| *Primary minerals* | | | | | |
| Olivine | 12.5 | 2.5 | | | 6.4 |
| Plagioclase | 54.4 | 60.5 | 39.4 | 53.6 | 46.1 |
| Clinopyroxene | 29.2 | 34.4 | 28.1 | 18.5 | 35.3 |
| Low-Ca pyroxene | 0.1 | | 9.2 | | |
| Opaques | | 0.3 | 9.0 | 12.8 | |
| *Secondary minerals* | | | | | |
| Clay minerals | | tr | | tr | 0.7 |
| Carbonate | | | | | |
| Chlorite | 0.2 | | | 0.1 | 0.7 |
| Brown amphibole | 0.1 | 0.2 | 1.3 | 3.0 | 0.4 |
| Actinolite | | 0.3 | 2.5 | 7.0 | 8.1 |
| Tremolite | 1.9 | | | | 1.1 |
| Magnetite | | 0.3 | | | 0.9 |
| Talc | | | | | |
| Plagioclase (neoblasts) | | | 10.1 | 2.0 | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | 1.1 | | | |
| Other | 1.5 | | | | |

**Table 3 (continued).**

| Core/section: | 118-735B-52R-4 | 118-735B-54R-5 | 118-735B-58R-3 | 118-735B-59R-4 | 118-735B-61R-1 |
|---|---|---|---|---|---|
| Interval (cm): | 88–94 | 117–119 | 107–114 | 29–35 | 85–87 |
| Rock Type[1]: | 3 | 3 | 2 | 2 | 2 |
| *Primary minerals* | | | | | |
| Olivine | | 0.5 | 9.8 | 6.9 | 5.6 |
| Plagioclase | 38.4 | 25.0 | 57.8 | 52.4 | 53.4 |
| Clinopyroxene | 24.9 | 44.7 | 30.6 | 39.6 | 37.4 |
| Low-Ca pyroxene | | | 0.5 | | |
| Opaques | 11.2 | 9.7 | 0.2 | 0.1 | |
| *Secondary minerals* | | | | | |
| Clay minerals | 0.2 | 1.8 | 0.1 | 0.1 | 0.2 |
| Carbonate | tr | | | | |
| Chlorite | tr | | | | |
| Brown amphibole | 5.6 | 1.8 | | tr | 0.7 |
| Actinolite | 14.9 | 5.4 | | 0.2 | 1.3 |
| Tremolite | 0.5 | | 0.5 | | |
| Magnetite | | | 0.2 | 0.1 | 0.6 |
| Talc | | | | 0.6 | 0.1 |
| Plagioclase (neoblasts) | 4.2 | 10.2 | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | 0.5 | | tr | |
| Other | | | 0.2 | | |

nopyroxene (1–20 mm), up to 1% spinel, and trace amounts of sulfide. In contrast, the fine-grained equigranular variety contains on average 22% olivine (0.1–1.5 mm), 67% plagioclase (0.2–2 mm), 9% clinopyroxene (0.1–2 mm), 0.5% orthopyroxene, 1.5% brown amphibole, and trace amounts of spinel and sulfide. The different mineralogies probably indicate a difference in the proportion of cumulus to intercumulus phases, the coarse poikilitic variety having a greater proportion of cumulus olivine and the finer-grained variety having a greater proportion of trapped intercumulus liquid.

Troctolites or troctolitic gabbros were noted either in visual core descriptions or in thin section descriptions in Cores 118-735B-12R, -20R, -38R, and -79R to -87R (Fig. 16). Their frequency and number increase toward the bottom of the hole. Furthermore, the coarser-grained olivine-rich variety appears to be restricted to Cores 118-735B-79R and -87R. This undoubtedly reflects both greater accumulation of olivine near the bottom of the hole and crystallization of more primitive (higher MgO) liquids. This is consistent with the geochemical data, which indicates higher bulk-rock Mg/(Mg + Fe) ratios in the last few cores.

## Iron-Titanium Oxide Gabbro

Iron-titanium oxide gabbros generally contain more than 5% opaque minerals. The opaque minerals are mainly ilmenite and magnetite, but minor amounts of sulfides, such as pyrrhotite,

**Table 3 (continued).**

| Core/section:<br>Interval (cm):<br>Rock Type$^1$: | 118-735B-49R-1<br>42–46<br>3 | 118-735B-50R-2<br>43–47<br>3 | 118-735B-50R-4<br>87–89<br>3 | 118-735B-51R-1<br>102–104<br>3 | 118-735B-52R-4<br>69–71<br>3 |
|---|---|---|---|---|---|
| *Primary minerals* | | | | | |
| Olivine | 0.1 | 0.1 | | | 0.1 |
| Plagioclase | 49.5 | 36.6 | 58.7 | 58.3 | 30.6 |
| Clinopyroxene | 26.6 | 16.8 | 15.2 | 12.2 | 37.8 |
| Low-Ca pyroxene | | | | | |
| Opaques | 15.1 | 21.9 | 5.9 | 7.3 | 15.0 |
| *Secondary minerals* | | | | | |
| Clay minerals | 0.8 | 0.4 | | | 1.1 |
| Carbonate | 0.4 | | | | |
| Chlorite | | | 0.5 | 0.5 | |
| Brown amphibole | 0.5 | 1.0 | 1.6 | 2.0 | 2.9 |
| Actinolite | 6.4 | 23.0 | 3.5 | 7.1 | 4.2 |
| Tremolite | tr | 0.2 | | 0.3 | 0.9 |
| Magnetite | | | | | tr |
| Talc | | 0.1 | | | |
| Plagioclase (neoblasts) | 0.6 | | 14.2 | 11.8 | 7.0 |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | 0.1 | | 0.1 | | |
| Other | | | | | |

**Table 3 (continued).**

| Core/section:<br>Interval (cm):<br>Rock Type$^1$: | 118-735B-62R-1<br>91–94<br>2 | 118-735B-63R-5<br>126–130<br>2,9 | 118-735B-65R-3<br>54–58<br>2 | 118-735B-67R-3<br>74–78<br>1 | 118-735B-68R-2<br>16–21<br>2 |
|---|---|---|---|---|---|
| *Primary minerals* | | | | | |
| Olivine | 7.0 | 5.9 | 9.0 | 2.0 | 13.4 |
| Plagioclase | 58.9 | 59.0 | 54.6 | 65.3 | 64.0 |
| Clinopyroxene | 31.8 | 24.9 | 34.5 | 19.3 | 20.7 |
| Low-Ca pyroxene | | | | | |
| Opaques | tr | tr | 0.2 | | |
| *Secondary minerals* | | | | | |
| Clay minerals | tr | 0.3 | 0.1 | 0.7 | |
| Carbonate | | tr | | | |
| Chlorite | | 0.6 | 0.2 | 0.6 | 1.0 |
| Brown amphibole | 0.3 | 3.9 | tr | 0.7 | tr |
| Actinolite | 1.2 | 3.3 | tr | 8.8 | |
| Tremolite | | tr | 0.8 | tr | 0.4 |
| Magnetite | | 0.5 | 0.1 | 0.2 | 0.3 |
| Talc | 0.3 | | | 1.9 | |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | | 0.2 |
| Other | | 1.6 | 0.2 | | |

chalcopyrite, and pyrite, are also present. Fresh iron-titanium oxide gabbro is gray and has dark gray specks of a metallic luster. When altered or metamorphosed, the rock becomes greenish. Iron-titanium oxide gabbro has the following general characteristics.

1. It contains calcium-poor pyroxenes (orthopyroxene and/or inverted pigeonite). Almost one-third of the iron-titanium oxide gabbros contain inverted pigeonite (Fig. 8), but this mineral is absent in other types of gabbro from Hole 735B.
2. Clinopyroxene usually has (001) exsolution lamellae, which are absent in other types of gabbro from Hole 735B.
3. Clinopyroxene commonly contains patches of orthopyroxene or inverted pigeonite, which show the same crystallographic orientation as exsolution in the host clinopyroxene.
4. Olivine is generally low in abundance (<2%) (Fig. 17), although a few olivine-rich iron-titanium oxide gabbros are present.

Iron-titanium oxide gabbros occur most abundantly from Sections 118-735B-46R-3 to 118-735B-56R-2 (Unit IV). Above lithologic Unit IV, there are some thin intervals (0.1–1 m) of iron-titanium oxide gabbro; these are in Sections 118-735B-23R-3, -24R-2, -24R-3, -28R-3, -28R-4, -32R-1, -34R-4, -37R-3, -38R-1, -38R-3, -38R-4, -44R-1, -44R-2, -44R-3, and -45R-1 (Fig. 8). At

**Table 3 (continued).**

| Core/section: | 118-735B-69R-3 | 118-735B-70R-1 | 118-735B-71R-3 | 118-735B-72R-2 | 118-735B-73R-1 |
|---|---|---|---|---|---|
| Interval (cm): | 86–92 | 80–84 | 0–5 | 56–61 | 54–57 |
| Rock Type[1]: | 2 | 2 | 2 | 2 | 2 |
| *Primary minerals* | | | | | |
| Olivine | 3.5 | 2.1 | 6.1 | 8.2 | 4.0 |
| Plagioclase | 53.4 | 57.2 | 54.5 | 65.0 | 41.1 |
| Clinopyroxene | 35.8 | 32.6 | 35.0 | 26.0 | 39.6 |
| Low-Ca pyroxene | | | | 0.1 | |
| Opaques | | | 0.2 | 0.2 | 0.2 |
| *Secondary minerals* | | | | | |
| Clay minerals | | 0.6 | tr | | 0.6 |
| Carbonate | | | | | |
| Chlorite | | | 0.2 | | |
| Brown amphibole | | 0.1 | tr | 0.1 | 11.4 |
| Actinolite | 3.9 | 5.2 | 2.0 | 0.4 | 1.9 |
| Tremolite | 2.5 | 1.5 | 1.5 | tr | 1.2 |
| Magnetite | 0.5 | 0.1 | | tr | |
| Talc | tr | tr | | | tr |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | | |
| Other | | | | 0.1 | |

**Table 3 (continued).**

| Core/section: | 118-735B-79R-7 | 118-735B-80R-2 | 118-735B-80R-6 | 118-735B-81R-5 | 118-735B-84R-5 |
|---|---|---|---|---|---|
| Interval (cm): | 99–102 | 35–40 | 6–9 | 1–7 | 80–82 |
| Rock Type[1]: | 5 | 5 | 5 | 2 | 2 |
| *Primary minerals* | | | | | |
| Olivine | 19.8 | 19.5 | 11.5 | 7.3 | 10.2 |
| Plagioclase | 72.6 | 64.6 | 50.3 | 59.1 | 51.1 |
| Clinopyroxene | 5.7 | 15.4 | 35.1 | 31.3 | 33.9 |
| Low-Ca pyroxene | | | | | |
| Opaques | 0.2 | | tr | tr | 0.4 |
| *Secondary minerals* | | | | | |
| Clay minerals | | 0.1 | 0.5 | 0.1 | |
| Carbonate | | | | | |
| Chlorite | | | | tr | |
| Brown amphibole | 1.7 | 0.3 | 1.7 | 0.2 | 0.8 |
| Actinolite | | | | 0.3 | 1.4 |
| Tremolite | | | | 0.5 | 1.5 |
| Magnetite | | | 0.3 | | 0.3 |
| Talc | | | | tr | tr |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | 0.1 | | |
| Other | | | | | |

the top of Unit IV, iron-titanium oxide gabbros are separated from olivine gabbros by a 60-cm-thick mylonite zone that cuts magmatic foliation developed in both the upper olivine gabbros and the lower iron-titanium oxide gabbros. The frequency of occurrence of iron-titanium oxide gabbros abruptly increases below Section 118-735B-46R-3 (Fig. 8). Similarly, the bottom of the unit is bounded by a mylonite zone about 6 m thick. Below this tectonic boundary, no iron-titanium oxide gabbro (except for minor opaque-rich zones) appears until a minor interval in Section 118-735B-73R-5 (Fig. 8). Within Unit IV, there are two intervals, 50–60 cm thick, where iron-titanium oxide-poor olivine gabbro occurs (Sections 118-735B-47R-3 and -48R-1). Contacts between the olivine gabbros and surrounding iron-titanium oxide gabbros are very sharp, and the abundance of opaque minerals changes abruptly (Fig. 18). Below Section 118-735B-73R-5, there are some intervals that contain minor iron-titanium oxide gabbro, such as in Sections 118-735B-76R-1, -76R-3, -76R-4, and -79R-7 (Fig. 8). Below Section 118-735B-80R-6, iron-titanium oxide gabbro occurs intermittently with relatively abundant intervals in Sections 118-735B-80R-6, -80R-7, -81R-4, -82R-1, -82R-5, and -82R-6 (Fig. 8). It is nearly absent from the interval between Section 118-735B-83R-1 and Section 118-735B-85R-3, and ilmenite layers (less than 10 cm) appear only in Sections 118-735B-83R-5 and -84R-5. Below Section 118-735B-85R-4,

**Table 3 (continued).**

| Core/section:<br>Interval (cm):<br>Rock Type$^1$: | 118-735B-74R-6<br>41–43<br>6 | 118-735B-75R-5<br>27–30<br>1 | 118-735B-76R-3<br>93–97<br>2 | 118-735B-78R-1<br>132–136<br>2 | 118-735B-79R-6<br>90–95<br>5 |
|---|---|---|---|---|---|
| *Primary minerals* | | | | | |
| Olivine | | 2.2 | 8.0 | 9.2 | 27.8 |
| Plagioclase | 57.0 | 57.7 | 63.8 | 51.3 | 68.0 |
| Clinopyroxene | 23.5 | 37.2 | 25.1 | 35.0 | 3.0 |
| Low-Ca pyroxene | 11.5 | | | | |
| Opaques | 5.8 | 0.1 | 0.1 | | tr |
| Apatite | 0.5 | | | | |
| *Secondary minerals* | | | | | |
| Clay minerals | tr | | 0.1 | 0.8 | tr |
| Carbonate | | | | | |
| Chlorite | | | 0.1 | 0.6 | |
| Brown amphibole | | | tr | 1.4 | 0.5 |
| Actinolite | 1.2 | 0.9 | 0.8 | 0.2 | |
| Tremolite | 0.5 | | | 0.1 | |
| Magnetite | | 0.9 | 1.1 | 0.6 | 0.2 |
| Talc | | | 0.5 | 0.2 | |
| Plagioclase (neoblasts) | | | | | |
| Clinopyroxene (neoblasts) | | | | | |
| Orthopyroxene (exsolution) | | | | | |
| Other | | 1.0 | | | |

**Table 3 (continued).**

| Core/section:<br>Interval (cm):<br>Rock Type$^1$: | 118-735B-85-7<br>17–19<br>5 |
|---|---|
| *Primary minerals* | |
| Olivine | 15.0 |
| Plagioclase | 65.0 |
| Clinopyroxene | 3.9 |
| Low-Ca pyroxene | 1.3 |
| Opaques | tr |
| *Secondary minerals* | |
| Clay minerals | |
| Carbonate | |
| Chlorite | 1.6 |
| Brown amphibole | 1.2 |
| Actinolite | 6.4 |
| Tremolite | 4.6 |
| Magnetite | |
| Talc | tr |
| Plagioclase (neoblasts) | |
| Clinopyroxene (neoblasts) | |
| Orthopyroxene (exsolution) | |
| Other | |

abundant iron-titanium oxide gabbro alternates on small scales (0.1–2 m) with iron-titanium oxide-free gabbro (olivine gabbro and troctolite) down to Section 118-735B-87R-6 (Fig. 8).

The primary minerals in iron-titanium oxide gabbros are plagioclase, clinopyroxene, iron-titanium oxide, ± olivine, and ± calcium-poor pyroxene (either orthopyroxene or inverted pigeonite). Minor amounts of reddish-brown hornblende, apatite, and sulfide are also present. The variation in abundance of iron-titanium oxide is wide ranging, from about 5% to 25%. Iron-titanium oxide gabbros having high concentrations of opaque minerals occur as layers ranging from 1 cm to 1 m thick. Iron-titanium oxides are ilmenite or magnetite with ilmenite exsolution lamellae. The volume ratio of ilmenite and magnetite varies from 1:2 to 2:1. Most of the iron-titanium oxide gabbros are poor in olivine and commonly contain less than 2% (Figs. 17 and 18). Some contain no olivine at all (e.g., Sample 118-735B-50R-4, 87–89 cm, Piece 1C). The modal abundance of calcium-poor pyroxene ranges from 0.5% to 3%. There are a few iron-titanium oxide gabbros that contain up to 10% olivine (e.g., Sample 118-735B-54R-3, 125–127 cm, Piece 3). These contain little calcium-poor pyroxene (as low as 0.1%). The reddish-brown hornblende (<1%) is probably primary, based on its high pleochroism and reddish tint. Primary sulfides include pyrrhotite, chalcopyrite, and pyrite. Their total modal abundance

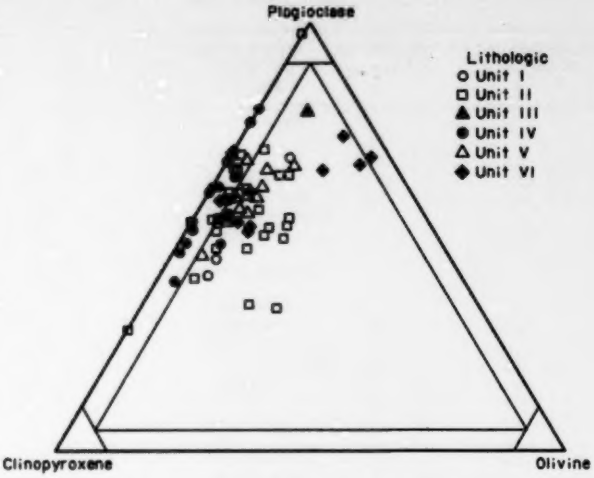

Figure 13. Modal proportions of plagioclase, clinopyroxene, and olivine. Proportions were determined by counting 2000 points at a spacing of 0.5 mm on 5- × 8-cm thin sections or 1000 to 1500 points at a spacing of 0.4 mm on standard thin sections.

ranges from trace amounts to 1%. Apatite (probably primary; see below) is present in some iron-titanium oxide gabbros (e.g., Samples 118-735B-54R-3, 125–127 cm, Piece 7, and 118-735B-55R-2, 50–55 cm, Piece 3A). Its mode is approximately 1%.

One peculiar gabbro containing 37.5% inverted pigeonite, 0.1% olivine, and 2.5% clinopyroxene was observed (Sample 118-735B-28R-3, 62–71 cm, Piece 4; Fig. 19). In thin section, this gabbro contains only 0.5% opaque minerals, but visual description of the core indicates higher concentrations of opaque minerals; thus, this pigeonite gabbro (or norite) may belong to the iron-titanium oxide gabbro suite. Another uncommon rock type that is probably related to the iron-titanium oxide gabbro is a coarse pyroxene layer, 1 cm thick, in olivine gabbro Sample 118-735B-35R-1, 45–47 cm, Piece 2E. Clinopyroxene and inverted pigeonite are the dominant minerals in this rock, with inverted pigeonite constituting approximately 10% of the layer. It is relatively rich in opaque minerals in thin section (2%). Thus, this layer can be treated as a pyroxene-rich layer of iron-titanium oxide gabbro.

Iron-titanium oxide gabbros are variably metamorphosed and altered. The abundance of secondary minerals as a result of metamorphism and alteration ranges from 2% to 25% and is commonly from 10% to 20%. The common secondary minerals are colorless amphibole and actinolite, which replace pyroxene or olivine; green to brown amphibole, which replaces clinopyroxene or red brown amphibole; yellowish-brown clay, which replaces olivine; carbonate, which replaces olivine or orthopyroxene; brown clay, which replaces iron-titanium oxide; and magnetite, which replaces olivine. Secondary pyrite (up to 1%) also occurs with green amphibole. Iron-titanium oxide gabbros also show varying degrees of deformation, with textures ranging from porphyroclastic to mylonitic.

Most of the iron-titanium oxide gabbros are partly deformed (Fig. 20) and metamorphosed, but igneous, undeformed textures are preserved in some specimens (Fig. 21). These specimens commonly show a magmatic foliation (Figs. 20 and 21) defined by elongated clinopyroxene and plagioclase crystals and aggregates of opaque minerals. The following description of primary igneous textures is based mainly on these fresh, relatively undeformed samples.

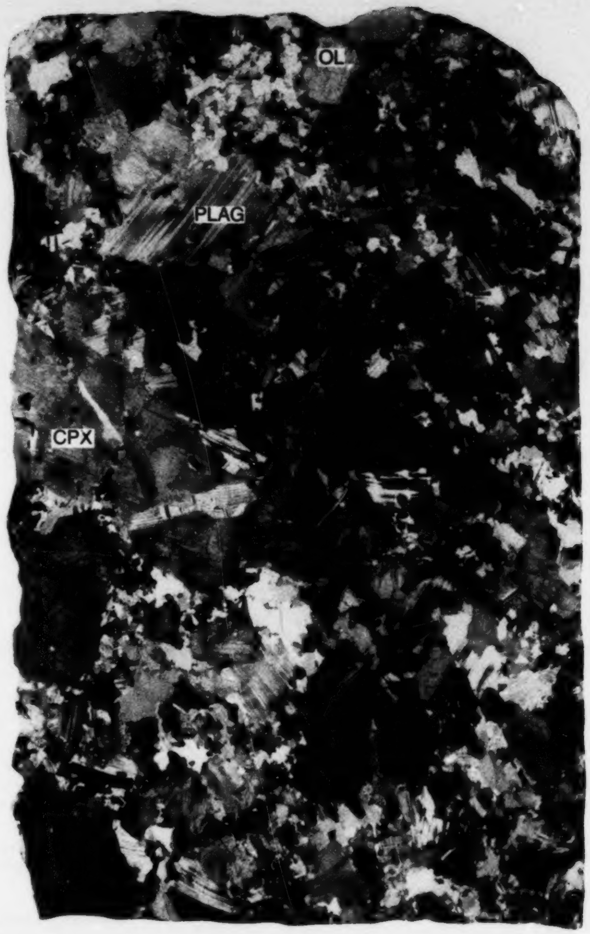

Figure 14. Polarized light photograph of 5- × 8-cm thin section showing a poikilitic gabbro (118-735B-27R-3, 73–81 cm, Piece 10). Note the 4-cm-wide clinopyroxene oikocryst in the center of the photograph. CPX = clinopyroxene; OL = olivine; PLAG = plagioclase.

Iron-titanium oxide gabbros from Hole 735B have average grain sizes that range from 0.3 mm for microgabbro to 30 mm for coarse-grained gabbro. The sizes of plagioclase, clinopyroxene, and opaque aggregates show concomitant variations.

Clinopyroxene is generally subhedral, rarely euhedral, and has an elongated shape. Oikocrysts of clinopyroxene are rare, compared with other types of gabbro from Hole 735B. In addition to (100) orthopyroxene exsolution lamellae, the clinopyroxene has (001) exsolution lamellae (orthopyroxene?), which are absent in clinopyroxenes in the olivine-bearing, iron-titanium oxide-poor gabbros. Even in porphyroclastic or mylonitic iron-titanium oxide gabbros, porphyroclasts of clinopyroxene have (001) exsolution lamellae. Large clinopyroxenes commonly contain patchy orthopyroxene or inverted pigeonite, which generally has the same crystallographic orientation as exsolution in the host clinopyroxene (Fig. 22). The patches of pigeonite are larger (0.5–1 mm) than those of orthopyroxene (0.1–0.3 mm) and occur in the cores of clinopyroxene crystals. These relationships indicate reaction between calcium-poor pyroxene and silicate melt to form calcium-rich pyroxene.

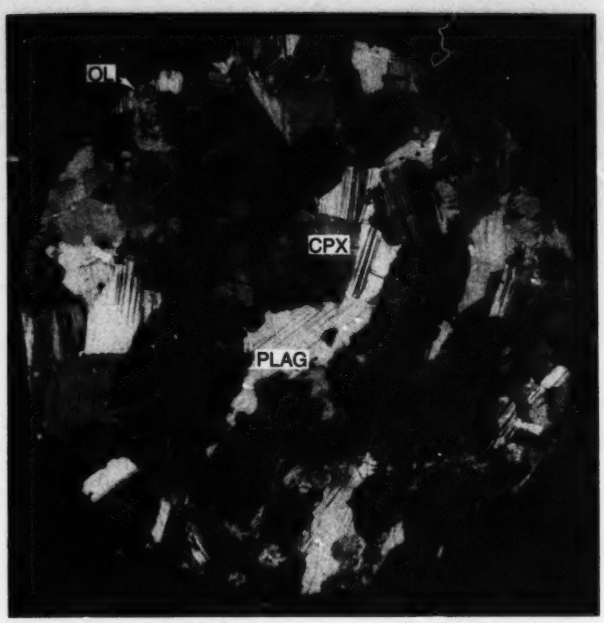

Figure 15. Polarized light photograph of thin section showing a granular gabbro (118-735B-36R-5, 131-133 cm, Piece 5E). The diameter of the round thin section is 2.5 cm. CPX = clinopyroxene; OL = olivine; PLAG = plagioclase.

Plagioclase is generally euhedral to subhedral, which suggests that it is a cumulus mineral (Fig. 23A). Euhedral plagioclase is enclosed in clinopyroxene or opaque minerals. It is commonly recrystallized into smaller grains by later deformation. Plagioclase compositions range from An $_{30-45}$, which are more sodic than those in the olivine gabbro and gabbro from Hole 735B.

When present, olivine is typically anhedral and occurs as thin films (0.1-0.3 mm) between opaque minerals and clinopyroxene (Fig. 23B). Olivine also occurs sandwiched between opaques and calcium-poor pyroxenes or plagioclase. These relationships suggest that pyroxenes were reacting with silicate liquid to produce iron-rich olivine and ilmenite. In iron-titanium oxide gabbros containing abundant olivine and rare calcium-poor pyroxene, olivine occurs as euhedral crystals. Olivine compositions range from $Fo_{30-55}$, which are more iron-rich than those in olivine gabbros and gabbros from Hole 735B.

Opaque minerals are generally anhedral and interfinger in a complex manner with clinopyroxene or plagioclase (Fig. 23A). These minerals also occur in plagioclase or clinopyroxene as euhedral inclusions. In two samples (Samples 118-735B-23R-3, 34-37 cm, Piece 2, and 118-735B-44R-2, 6-8 cm, Piece 1A), we found intergrowths of opaque minerals and orthopyroxene.

Calcium-poor pyroxenes are present as patches in clinopyroxene or as isolated grains generally in contact with, or enclosed in, clinopyroxene crystals. They are generally anhedral, but some are subhedral. Inverted pigeonite is euhedral. It has abundant clinopyroxene exsolution blebs, typically parallel to (001) from the pigeonite inversion. The host orthopyroxene also has thinner exsolved lamellae of clinopyroxene parallel to (100). Twinned crystals in pigeonite gabbro show a typical herringbone structure (Fig. 19B). The exsolution blebs are commonly irregular or parallel to (100). Clinopyroxene exsolution lamellae in calcium-poor pyroxenes have the same optical orientation as the surrounding large grains of clinopyroxene.

Reddish-brown hornblende commonly accompanies orthopyroxene patches in clinopyroxene or opaque minerals. Its grain size ranges from 0.1 to 0.3 mm. Apatite crystals from 0.1 to 0.5 mm long are present as euhedral to subhedral inclusions in opaque minerals or as polycrystalline aggregates interstitial to plagioclase and olivine. This suggests a primary origin for the apatite. See the "Oxide and Sulfide Mineralogy" section (this chapter) for textural characteristics of opaque minerals in iron-titanium oxide gabbros.

### Basalt

A single basaltic dike having chilled contacts against gabbro was recovered between Section 118-735B-23R-4 at 66 cm and Section 118-735B-23R-5 at 25 cm. The contacts between basalt and gabbro are sharp and planar; crystals of plagioclase in the gabbro wall rock are abruptly truncated at the contact. Recovery of homogeneous basalt between these two contacts suggests a vertical thickness of approximately 1 m for the dike. The basalt is aphyric, fine-grained, and gray.

Grain size and texture within the basalt vary across the dike. At the dike margins one can see cryptocrystalline bands 1.0-1.5 mm wide that have subhedral plagioclase and olivine microphenocrysts aligned parallel to the contact. Inward, birefringent crystallites of clinopyroxene and/or olivine can be detected in the groundmass; the texture is incipiently intersertal, although groundmass crystals are less than 20 $\mu$m in size. Approximately 1 cm from the cryptocrystalline zones, the maximum microphenocryst size is only 0.4 mm. This is significantly smaller than the average microphenocryst size adjacent to the gabbro contact and may represent flow differentiation. The interior of the dike has a fine-grained intersertal texture and contains clinopyroxene crystals between 0.05 and 0.2 mm and plagioclase laths up to 1.2 mm in length. These textural variations are analogous to those described for planar dike margins from the sheeted dike complex of Hole 504B (Kempton, 1985). A single anhedral crystal of golden-brown chromium-spinel, 0.2 mm in diameter, was observed in the basalt and is probably a xenocryst.

Fine-grained, metamorphosed rocks that appear to intrude gabbros of Units I and II were observed in Sections 118-735B-6D-1 and 118-735B-19R-5. In Sample 118-735B-6D-1, 92-107 cm, Piece 18, a thin, apparently nonfoliated layer is enclosed within a porphyroclastic to mylonitic section. Petrographically, this sample was identified as an iron-titanium oxide-rich mylonite. In Section 118-735B-19R-5, greenish-gray, nonfoliated rocks sharply crosscut the surrounding coarse-grained, foliated metagabbro. This sample was identified petrographically as an amphibolitized, but relatively undeformed, microgabbro.

### Felsic Rocks

Fragments of a trondjhemite dike were recovered in Sample 118-735B-53R-5, 35-45 cm, Piece 3; possible effects of mixing between trondjhemite and gabbro were observed in adjacent Sections 118-735B-53R-3, 118-735B-53R-4, and 118-735B-54R-2. The trondjhemite is a medium-grained, leucocratic rock composed of approximately 75% plagioclase, 20% quartz, 2% biotite, 2% clinopyroxene, and 1% magnetite. Plagioclase occurs as blocky, subhedral crystals, which are relatively homogeneous in the cores but are strongly zoned over the outer 0.02 mm of the rims. Grain size averages about 0.5 mm, although a few crystals as large as 1.5 mm occur. Quartz generally occurs as an interstitial phase between plagioclase, but one large crystal, 1.5 mm in diameter, exhibits a euhedral outline while actually being composed of several subcrystals with independent undulose extinction. Clinopyroxene, now largely replaced by pale green actinolite, has an equant, euhedral to subhedral morphology and ranges from 0.2 to 0.5 mm in size. Biotite poikilitically encloses euhedral plagioclase crystals.

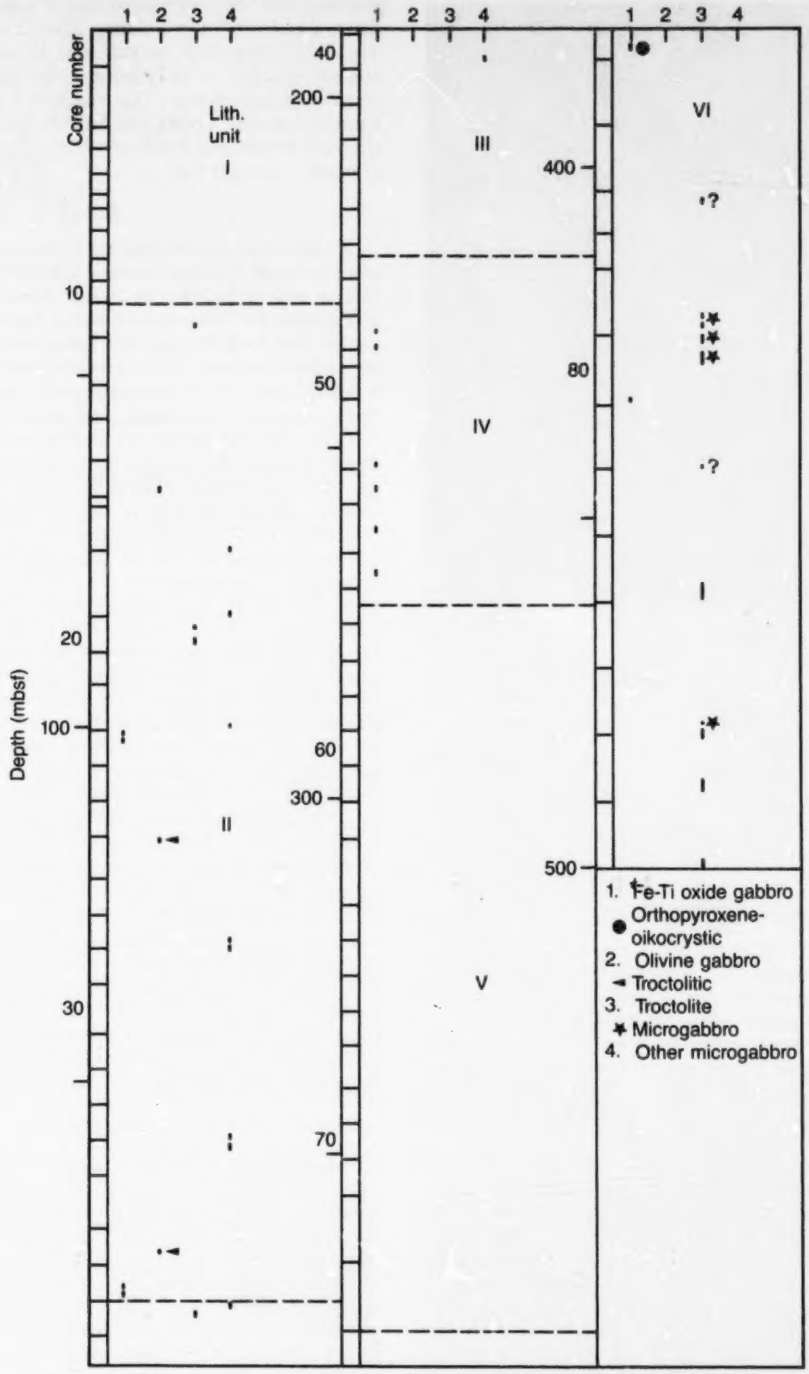

Figure 16. Downhole plot showing the location of troctolites and different types of microgabbros. Iron-titanium oxide microgabbros are plotted as small dots in column 1. Olivine microgabbros are plotted as small dots in column 2, with troctolitic varieties indicated by arrows. Troctolites are shown in column 3, with medium-grained varieties indicated by small dots and fine-grained varieties by stars. Metamorphosed microgabbros of questionable lithology are plotted in column 4.

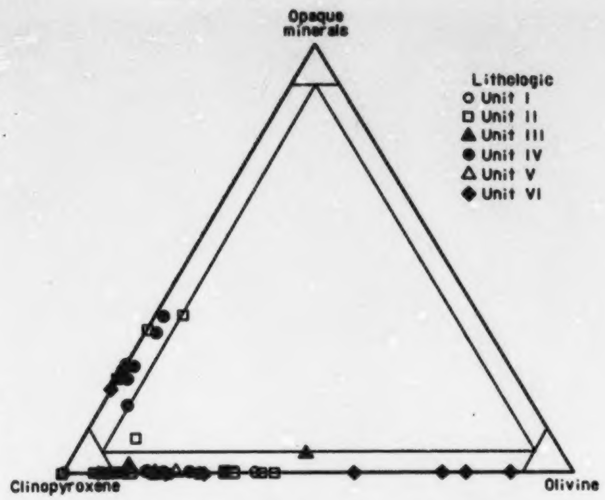

Figure 17. Ternary plot showing relative abundance of opaque minerals, clinopyroxene, and olivine. Iron-titanium oxide gabbros show distinct depletion of olivine.

The trondjhemite intrudes iron-titanium gabbro of Unit III (see "Lithostratigraphy" section, this chapter). The contact between these two rock types is planar, and crystals in the gabbroic wall rock are truncated by the contact. In addition, feldspar adjacent to the contact has strongly zoned rims (0.1 mm wide) similar to plagioclase in the trondjhemite.

The gabbroic wall rock adjacent to the trondjhemite has been metasomatized as a result of the intrusion, as seen by the presence of abundant secondary mica along the contact. Ilmenite in the gabbro is surrounded by brown mica, possibly phlogopite. This brown mica is zoned to, or overgrown by, an unidentified green mica having high birefingence. Olivine is replaced by colorless amphibole and magnetite.

Intense mixing of felsic and gabbroic material was noted in several sections above and below the recovered trondjhemite. In Section 118-735B-53R-4, the mixed material is described as broken, angular fragments of gabbro included in felsic material. Elsewhere, the mixing is more complete and the gabbroic fragments appear to be partially disaggregated and digested by the felsic material. Below the trondjhemite in Section 118-735B-54R-2, felsic rocks are more strictly confined to veins approximately 1-2 cm wide. Traces of biotite were noted in a few pieces throughout this section.

Although not trondjhemitic in composition, felsic veins free of amphibole were observed as high in the section as Section 118-735B-43R-4 and periodically thereafter. These veins are composed of subhedral to euhedral plagioclase, subhedral to euhedral clinopyroxene, epidote ± sphene ± chlorite ± carbonate. We are not sure whether these veins are magmatic or hydrothermal, but we prefer a hydrothermal origin (see "Metamorphism and Alteration" section, this chapter). The abundance of these veins near the trondjhemitic intrusion suggests that they may be genetically related.

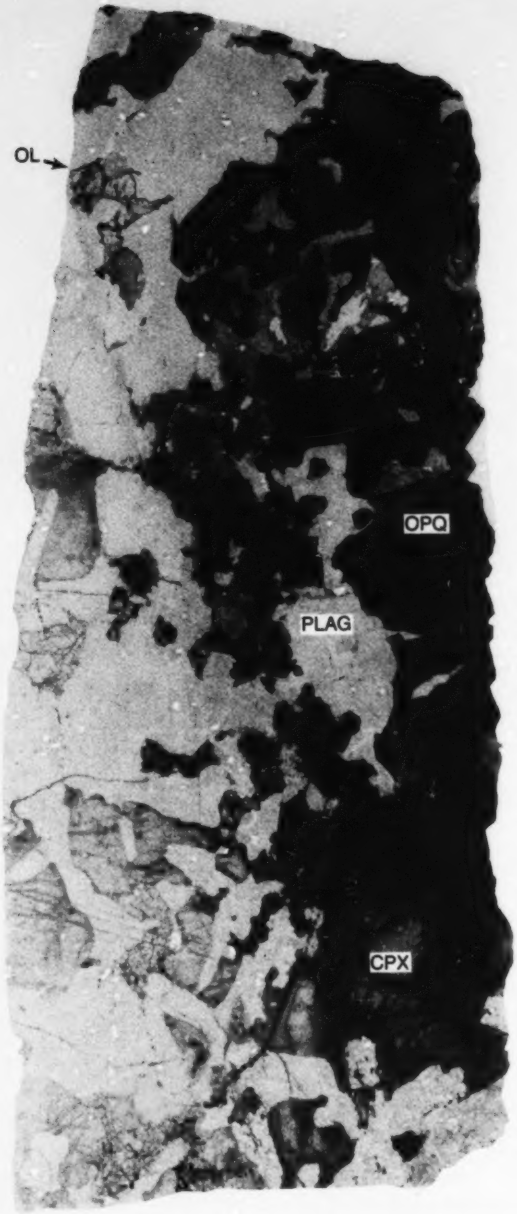

Figure 18. Polarized light photograph of thin section showing the contact between an olivine gabbro and an iron-titanium oxide gabbro (118-735B-44R-1, 113-120 cm, Piece 2I). CPX = clinopyroxene; OL = olivine; PLAG = plagioclase; OPQ = opaque minerals.

## Textural Variations

Some intervals in Hole 735B have distinct modal, phase, and size gradations. Variations in modal abundances and crystal size in individual samples of plutonic rocks have been documented in several samples dredged from fracture zones and rift valleys (e.g., Tiezzi and Scott, 1980; Engel and Fisher, 1975; Bloomer et al., 1985; Meyer et al., 1988). Such samples usually include only a single contact, either from one modal assemblage to another or between two grain sizes, and it has not been possible to examine large-scale layering in mid-ocean ridge plutonic complexes. Here, we describe briefly the principal types of modal and textural variation seen in the gabbroic rocks from Hole 735B.

Although layering is well developed in the rocks from this hole, it is not the distinctive rhythmic phase layering so common in large basic intrusions like the Stillwater or Bushveld complexes, or even in the plutonic parts of many ophiolite complexes. The layering is locally, and often subtly, developed. Re-

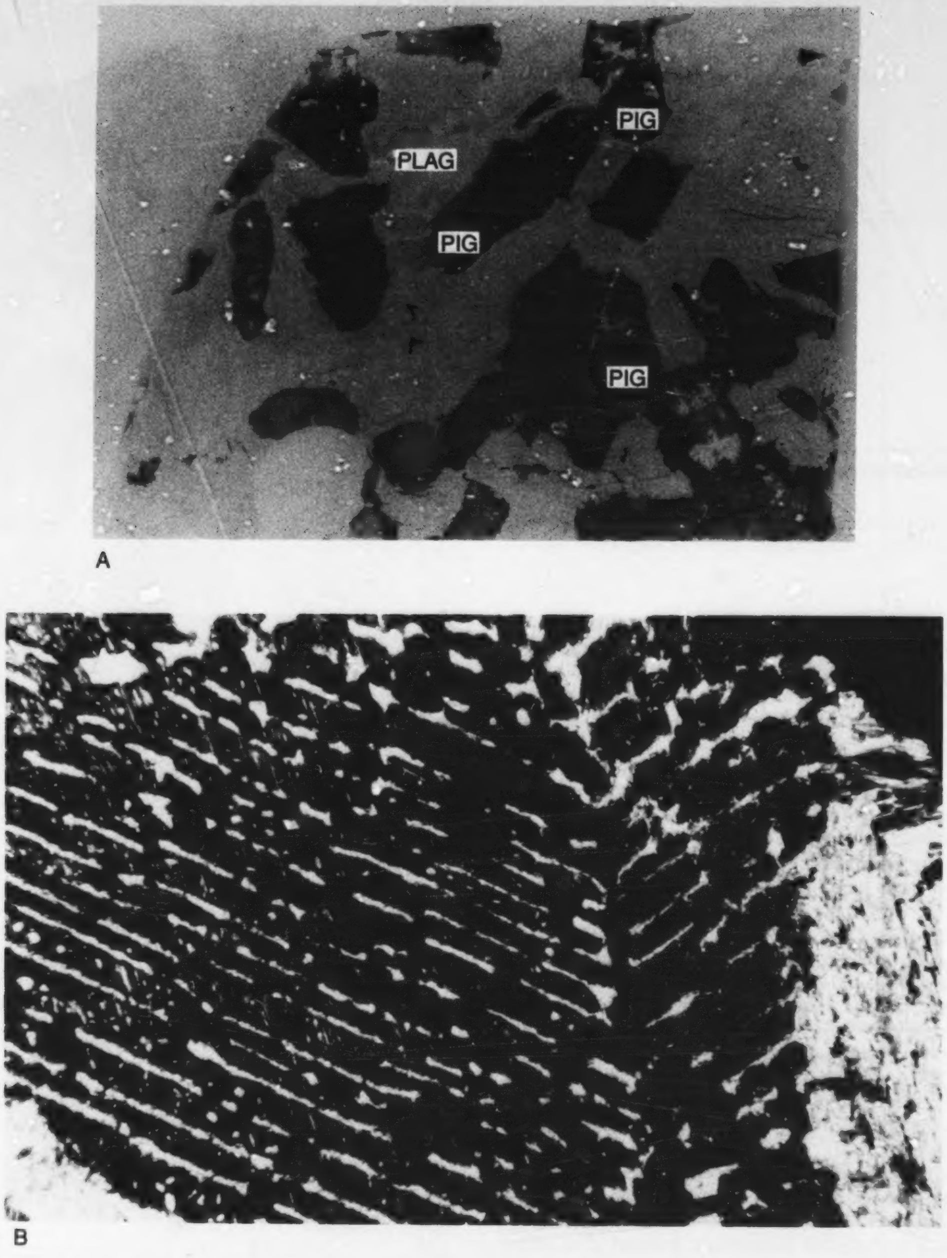

Figure 19. A. Plane light photograph of 5- × 8-cm thin section showing pigeonite gabbro containing 40% euhedral inverted pigeonite (gray mineral in photograph; 118-735B-28R-3, 62–71 cm, Piece 4). B. Photomicrograph of inverted pigeonite in pigeonite gabbro, showing herringbone structure. Crossed nicols. Field of view is 2.5 mm. PIG = pigeonite; PLAG = plagioclase.

covery from Hole 735B, particularly in the deeper parts, was nearly continuous (Fig. 5) and provided a more detailed sampling than is generally available even from subaerial gabbroic complexes. The cored material was described centimeter by centimeter. Many of the size and textural variations identified from these descriptions are subtle and might not be recognized as layering if examined in the field. The preceding is not meant to diminish the importance of the textural variations in the gabbroic rocks from Hole 735B, but it is meant to alert the reader that there are some important differences between this layering and that normally associated with layered basic intrusions.

Distinctly modal- or size-layered features were observed in about 25% to 28% of the sections in Units II, III, V, and VI and in about 40% of the sections in Unit IV. Intervals of 3 to 7 m of relatively massive gabbro, with little evidence of size or modal layering, are common in all of the lithologic units. In fact, massive gabbros are the most common textural type in the undeformed parts of the core. Many of the textural transitions are lo-

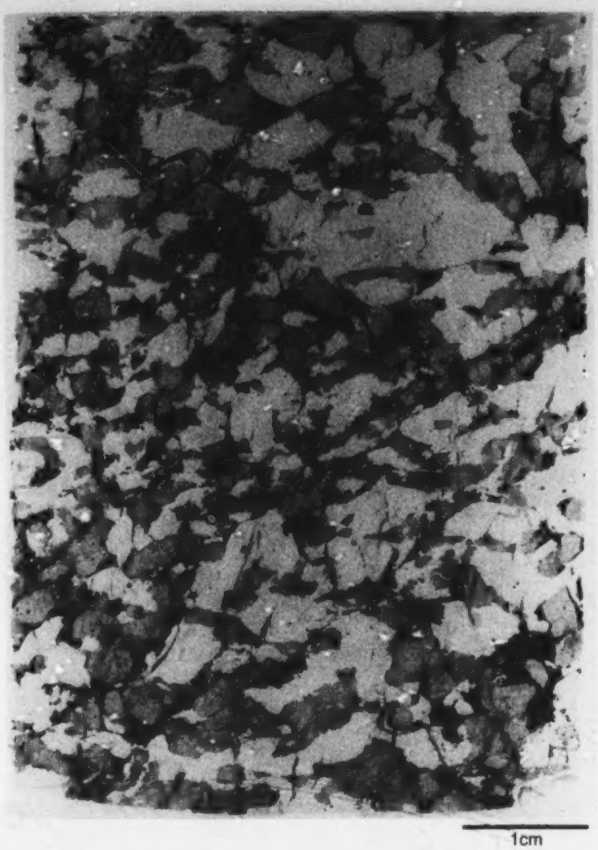

Figure 20. Plane light photograph of thin section showing slightly deformed iron-titanium oxide gabbro (118-735B-52R-4, 88-94 cm, Piece 4B). Elongated plagioclase (white) and pyroxene (gray) crystals define a primary igneous lamination cut by several microfaults. Redistribution of opaque minerals (black) along these microfaults clearly defines a foliation due to deformation.

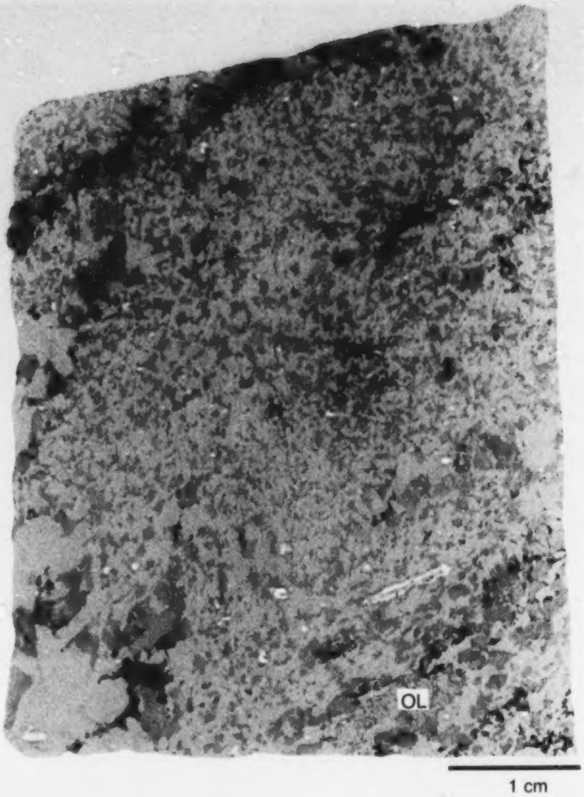

Figure 21. Plane light photograph of 5- × 8-cm thin section showing undeformed iron-titanium oxide gabbro with magmatic foliation (118-735B-46R-3, 121-128 cm, Piece 10). The foliation is defined by elongated euhedral laths of plagioclase (white) and thin opaque-rich layers (black). Gray grains are clinopyroxene and minor olivine. Large olivine (OL) is present at lower right corner, which is also elongated parallel to the foliation.

cally developed, particularly the coarse- to fine-grain-size changes. In extreme cases, textures can change from very coarse- to fine-grained over 2 cm (Fig. 24). The type of layering observed in the core from Hole 735B is probably laterally discontinuous. The major mineralogical changes in the section occur between Units III and IV and Units IV and V. The latter is definitely a tectonic contact, and the former probably is as well. Unit V has some distinct troctolitic intervals, at least one of which (in Core 118-735B-83R) represents distinct phase layering. However, most of the troctolitic layers are fine-grained microgabbros that may be intrusive into the coarser-grained olivine gabbro.

## Small-Scale Textures

The olivine gabbros are adcumulates and mesocumulates, with cumulus plagioclase and olivine and intergranular to ophitic clinopyroxene (Fig. 25). Moderately to weakly developed igneous lamination, defined principally by subparallel orientation of plagioclase laths, occurs locally (Fig. 26). Large oikocrysts of clinopyroxene (up to 10 cm in size) are common in the olivine gabbros. These large oikocrysts commonly are elongated perpendicular to the principal layering in the gabbros (Fig. 27). On a smaller scale, 1-cm oikocrysts of orthopyroxene in a microgabbro also exhibit a subvertical orientation. A similar vertical orientation of euhedral and subhedral plagioclase was noted in some cores and can be identified on a smaller scale in phase-layered gabbros (Fig. 28). This type of crystal growth normal to the layering is reminiscent of the crescumulates seen in the Rhum Intrusion (Wager et al., 1960).

Granular textures occur in many samples; in some cases, subhedral clinopyroxene, as well as plagioclase, appears to have been a cumulus phase. These granular textures are most common in the iron-titanium oxide gabbros and in the coarse intervals in the olivine gabbros. In the iron-titanium oxide gabbros, the intergranular phases include a low-calcium pyroxene, olivine, and the oxide. The igneous lamination is more common in the oxide-bearing gabbros (Fig. 27).

## Layering

Three principal types of layering can be identified in the gabbroic samples from Hole 735B. The first is modal layering, defined by variations in modal abundances of individual phases. Most common are layers rich in olivine (Fig. 29). These layers tend to be 1 to 5 cm thick, but may be up to 25 cm thick. They are repeated in single sections of core and are spaced at irregular intervals from 5 to 50 cm apart. Abundances of olivine may be from 5% to 30%, compared with abundances of 1% to 5% in the other layers. The olivine-rich zones do not correspond in any consistent way with coarse- or fine-grained intervals in the size-graded layers.

Phase layering, defined by abrupt and persistant appearance or disappearence of a phase, was not observed in these gabbros.

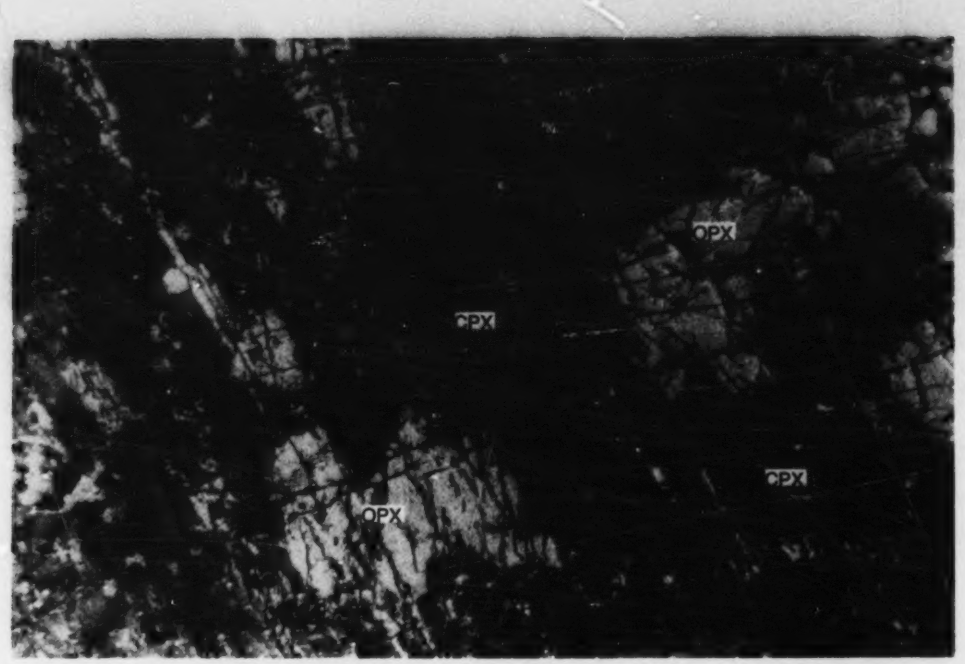

Figure 22. Polarized light photomicrograph of patchy orthopyroxene (OPX) in clinopyroxene (CPX). Field of view is 2.5 mm (118-735B-34R-4, 8–12 cm, Piece 2).

The nearest analogs are 1- to 5-cm-thick plagioclase- and pyroxene-rich layers, usually occurring in the coarser-grained parts of the size-graded intervals. In some cases, these layers approach pyroxenites or anorthosites in composition but have a limited vertical extent. In many cases, they are made up of only a one- or two-crystal-thick layer (Fig. 28).

The most common type of layering in these gabbros is defined by gradations in size. These graded units are coarse or very coarse layers fining upward to fine- and medium-grained layers (Fig. 30). These units are most commonly graded from crystal sizes of 10 to 20 mm to medium-grained intervals of 1 to 5 mm. The units vary in thickness from 10 to 100 cm; the transitions in grain size may be either gradational or quite sharp. Two to four graded intervals of various thicknesses may occur in a single section.

The third type of layering observed in the gabbros is defined by the contacts between gabbros and microgabbros. These microgabbros are fine-grained, equigranular units that occur in three distinct styles. The first style resembles rather large dike- or sill-like bodies, with sharp contacts against the host gabbros (Fig. 31). These often cut across the inferred layering orientation. The most common microgabbro occurrence is as small pods within a medium- or coarse-grained gabbro. These pods often are repeated within a short section, and their contacts define a foliation having an orientation similar to that inferred from graded sequences in other parts of the core (Fig. 31). The third style of microgabbro is as very small clots sandwiched between medium-grained gabbro (Fig. 31). The microgabbros as a group probably formed through a range of processes, including segregation of trapped liquids, intrusions of liquids into crystallizing gabbros, and rapid, localized changes in cooling rates.

## OXIDE AND SULFIDE MINERALOGY

### Introduction

Oxide and sulfide minerals are strikingly abundant in many Hole 735B gabbros. Their distribution in the cores reflects important aspects of the crystallization, deformation, and metamorphism experienced by the rocks.

The great diversity of gabbro types at Site 735 allows us to evaluate in more detail the oxide and sulfide mineralogy in an oceanic setting than may ever be possible using basalts. Not only are fairly extreme compositions, ranging from troctolites to trondjhemites, present but most of the rocks are cumulates that have retained some fraction of intercumulus liquid, which eventually crystallized oxides and sulfides in intergranular spaces. In a few specimens, oxides and sulfides are primary cumulus phases. In addition, two-pyroxene gabbros and oxide-rich ferrogabbros, compositions representative of rather evolved basaltic parents, are common. With such rocks we may be able to study the sequence of crystallization of oxide and sulfide minerals in some detail and relate it to an appropriate stage of fractionation.

### General Distribution of Oxides and Sulfides in Hole 735B

The abundance and to some extent the compositions and proportions of oxides and sulfides in Hole 735B reflect the rock compositions, their mechanical deformation, and their metamorphism under amphibolite facies conditions. The rocks cored are gabbroic, except for one basalt dike. The gabbros are primarily cumulates but are intensely deformed near the top and bottom of the hole and locally deformed inbetween (see "Metamorphism and Alteration" section, this chapter). The most important intermediate zone of deformation is above a fault at 272 mbsf, at the level of Core 118-735B-56R (Fig. 7).

#### *Spinel*

Chromian-spinel occurs in only one interval of troctolite, an olivine-plagioclase cumulate in Core 118-735B-83R. It is dark brown, almost opaque, up to 0.2 mm in diameter, and forms octahedral, sometimes skeletal crystals. The crystals are darker brown than either of the two grains of spinel observed in the basalt dike in Core 118-735B-23R. These grains have rounded, presumably resorbed outlines, and are zoned with very dark vermi-

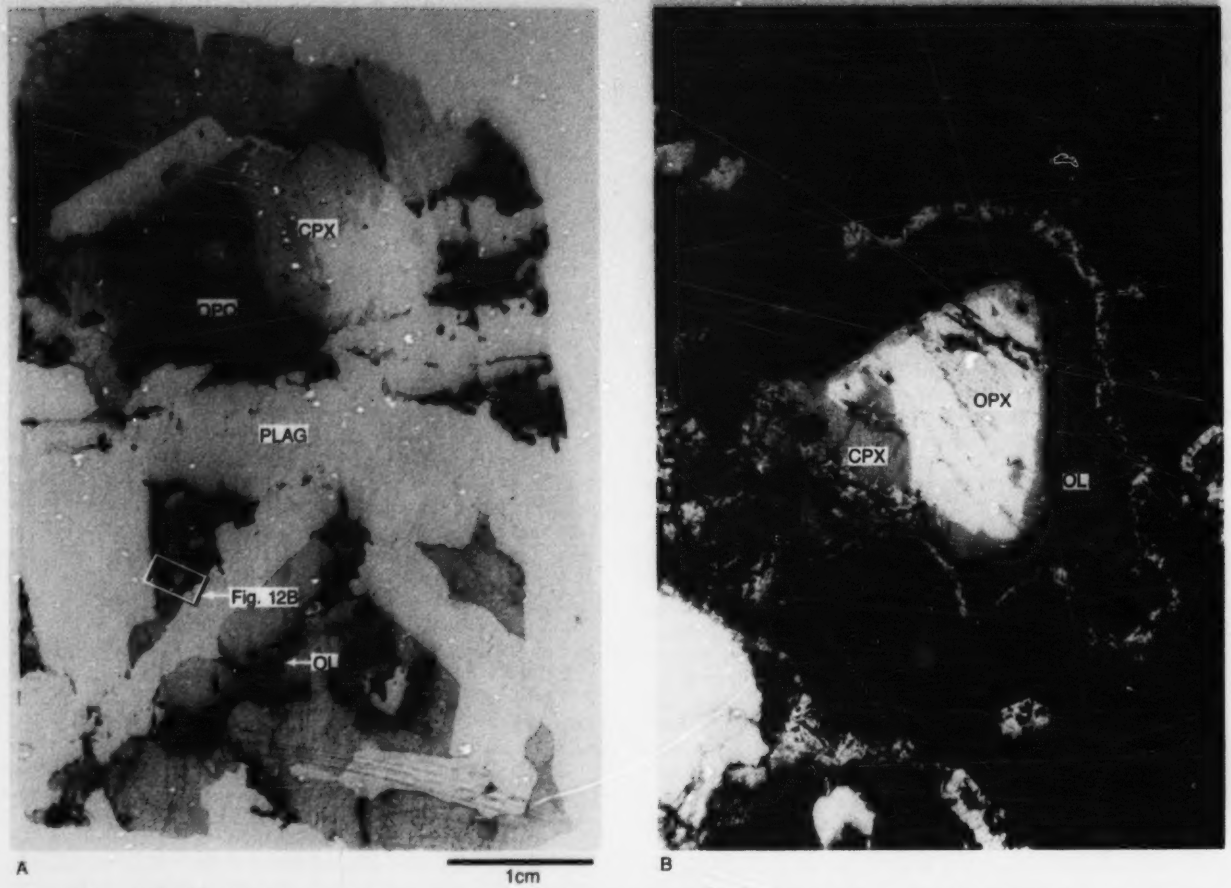

Figure 23. A. Plane light photograph of thin section showing undeformed iron-titanium oxide gabbro with interfingering relationships between opaque minerals (OPQ) and clinopyroxene (CPX) or plagioclase (PLAG); OL = olivine (118-735B-34R-4, 8–12 cm, Piece 2). Rectangle indicates view of photomicrograph. B. Photomicrograph of orthopyroxene (OPX) in clinopyroxene (CPX) rimmed by olivine (OL), which is further surrounded by opaque minerals. Crossed nicols. Field of view is 2.5 mm.

cular rims. A few grains in the troctolite enclose small, roughly cubic but rounded grains of a white mineral, distinctly anisotropic in cross-polarized light (pentlandite?). Other grains have pyrrhotite-chalcopyrite intergrowths at their edges similar to intergranular sulfides elsewhere in the section.

### *Iron-Titanium Oxides*

Iron-titanium oxides are the most abundant opaque phases in most of the gabbros and correlate well with bulk-rock compositions as well as the lithology and petrography.

The abundances of iron-titanium oxides vary regularly within the lithologic units. These oxides are minor in Unit V and the top five cores of Unit VI; sporadically abundant in the more iron-rich parts of Units I, II, and the remainder of Unit VI; and very abundant in the ferrogabbros of Unit IV. In Units I and II, iron-titanium oxides vary from virtually 0% to as much as 10%. Thin sections containing more than 2% ilmenite and magnetite occur in Cores 118-735B-2R, -4R, -10R through -14R, -19R, -23R, -24R, -30R, -31R, -32R, and -34R, with highs of about 7% in a porphyroclastic metagabbro in Core 118-735B-4R (20 mbsf), and 10% in each of Cores 118-735B-32R (149 mbsf) and 118-735B-34R (165 mbsf). Similarly, in the iron-rich lower parts of Unit VI, thin sections containing more than 2% iron-titanium oxides occur in Cores 118-735B-82R, -86R, and -87R. However, no slide has more than 5% of combined ilmenite and magnetite.

In the most iron-enriched gabbros of lithologic Units III and IV, several samples between Cores 118-735B-38R and 118-735B-44R have 2%–4% iron-titanium oxides. Many samples in Cores 118-735B-44R and -56R have at least 5% oxides, several have as much as 20%, and one sample, in Core 118-735B-47R (228 mbsf), has more than 50% combined ilmenite and magnetite.

Deformation greatly influences the distribution of these oxide minerals in Unit I and parts of Unit VI. In both units, coarsely porphyroclastic metagabbros have the greatest abundances (3%–7%), while finer-grained gneissic gabbros and mylonites typically have only 1%–2%. In ferrogabbros from Units III and IV, most specimens exhibit primary textural relations among oxides, sulfides, and silicates, but in some cases, the rocks also are sheared and granulated and have metamorphic fabrics. Gabbros from Unit V are rarely intensely deformed; thus, most oxides are simply intercumulus minerals in low abundance. The proportions of oxide minerals in the few mylonitized olivine gabbros are no greater than in the immediately surrounding undeformed rocks. Gabbros in the lower parts of Unit VI are not so deformed as those in the geochemically similar gabbros of Units I and II. Primary textures occur in some samples, metamorphic fabrics in others, and a few are only partly

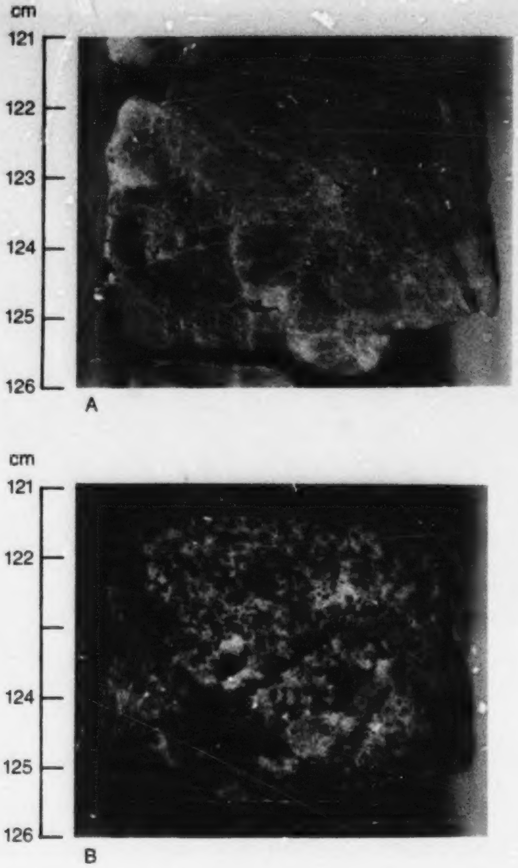

Figure 24. Grain-size variations between cut (A) and cored surface (B) of Section 118-735B-64R-1. Note the change from very coarse-grained (2–3 cm) on the cut surface to fine- or medium-grained on the cored surface.

recrystallized, with both primary and metamorphic oxide-silicate relationships.

The proportion of ilmenite to magnetite in given samples is difficult to estimate, especially if the rocks are strongly mylonitized. In the deformed rocks, the iron-titanium oxides occur in veins or seams along the foliation. The two minerals are intergrown and, in some cases, magnetite has tiny exsolution lamellae of ilmenite. In the largest seams, the ilmenite is broken into plates many times larger than granulated plagioclases or clinopyroxenes in the same samples. The plates are bounded by curvilinear fractures, and each has a slightly different extinction direction. Because there is no alteration along the fractures, plates may have been produced simply by expansion of the minerals when they were brought to the sea surface. A few samples have ilmenite with hematite exsolution lamellae developed along similar fractures, which must have been produced *in situ*. These data suggest that ilmenite is by far more abundant than magnetite in these deformed rocks, perhaps in the ratios 2:1 to 3:1.

Where primary textural relationships can be ascertained, the proportions seem reversed. In undeformed olivine gabbros and troctolites of Unit V and the upper part of Unit VI, magnetite is more abundant than ilmenite, but the abundances of both are very low. Here, and in all other cases, ilmenite exsolved from magnetite is not considered primary, but is grouped with the magnetite to obtain the proportions of magmatic oxides.

The proportion of ilmenite to magnetite in ferrogabbros varies, with sometimes one, sometimes the other, predominating. In typical samples, the ratio of magnetite to ilmenite is perhaps 2:1. Also, ilmenite in the ferrogabbros began to crystallize before magnetite, which commonly encloses it subophitically. In some cases, the oxides grow into embayments in the silicate minerals, and in others, the silicates are poikilitically enclosed in oxides or vice versa. The high abundance of magnetite in gabbros with primary textures suggests that the $TiO_2$ was metasomatically increased in the metagabbros.

These intergrowths of generally coarse-grained ilmenite and magnetite are the most striking aspect of the opaque mineralogy of Hole 735B gabbros. In fact, the intergrowths in both undeformed and foliated rocks also typically include sulfide minerals, as described below. But there are other magnetites in the gabbros associated with minerals transformed during amphibo-

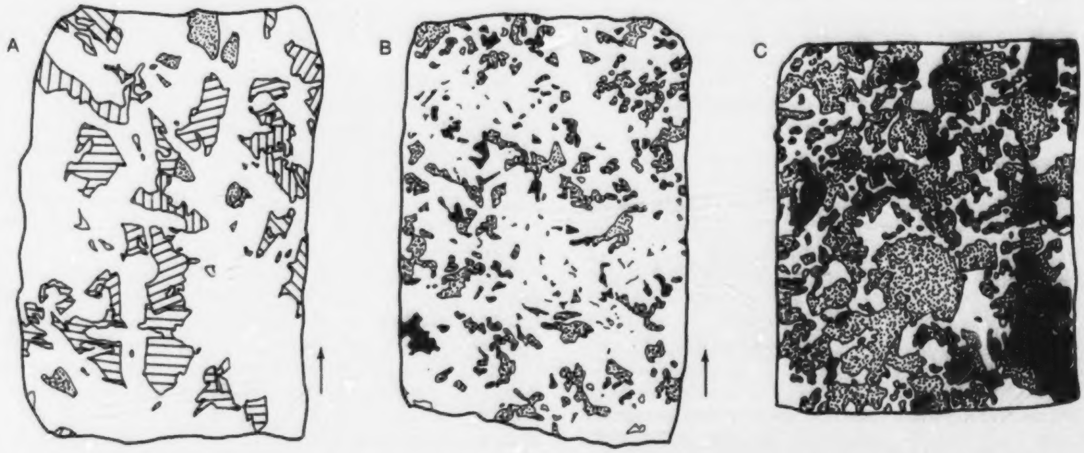

Figure 25. Grain tracing of individual pieces. Each slab is 5 cm wide. A. Clinopyroxene oikocrysts (lined) between cumulate plagioclase (white) and olivine (dotted) (118-735B-74R-5, 85–95 cm, Piece 3B). B. Skeletal clinopyroxene oikocrysts (black) in a plagiocase-rich troctolite (118-735B-79R-5, 81–90 cm, Piece 6A). Olivine is dotted and plagioclase is white. The clinopyroxene fragments in the center of the sketch are part of an optically continuous grain. C. Intergranular clinopyroxene (black) in an olivine-rich troctolite (118-735B-87R-5, 110–118 cm, Piece 11A). Olivine is dotted and plagioclase is white.

Figure 26. Polarized light photograph of 5- × 8-cm thin section showing igneous lamination in an olivine gabbro (118-735B-72R-2, 56-62 cm, Piece 1D). OL = olivine; CPX = clinopyroxene; PLAG = plagioclase.

lite-facies metamorphic conditions. These are typically much finer grained, are less reflective, have vermicular to skeletal morphologies, and occur with amphiboles, talc, and/or chlorite. They are particularly important to rock magnetic properties because they evidently carry the stable component of natural remanent magnetization in the rocks (see "Paleomagnetics" section, this chapter). The coarse magnetites in the magnetite-ilmenite-sulfide intergrowths give the rocks high magnetic intensities, but they are quite readily demagnetized.

A few specimens near the top of the hole and again at the very bottom contain minor iron oxyhydroxides that are sometimes fairly reflective and that are produced by transformation of ferromagnesian silicates during oxidative alteration. These are usually associated with clay minerals in the replacement of clinopyroxene and/or green amphibole in mylonites of Cores 118-735B-1D through -10D, and olivines in other parts of the core.

### Sulfide Minerals in Undeformed Gabbros

The abundance of sulfide minerals in the gabbros is typically less than 1%, but both the abundances and proportions of sulfides follow the pattern of the iron-titanium oxides in the different rock types.

Sulfide minerals are least abundant in the olivine gabbros and troctolites of Unit V and the upper part of Unit VI, or in similar rocks in the other units. Even so, they are more abundant than iron-titanium oxides in these rocks. Sulfides in the spinel-bearing troctolite in Core 118-735B-83R have already been described.

Sulfide minerals are more abundant in the noritic gabbros than in the olivine gabbros and are more abundant still in oxide-enriched ferrogabbros. In all these rocks, however, the proportion of iron-titanium oxides greatly exceeds that of sulfides.

Pyrrhotite and chalcopyrite are the principal phases in the olivine cumulates, with the former more abundant than the latter. The two appear to have precipitated together inasmuch as they are intergrown in globules and blebs, an indication of sulfide immiscibility in basaltic parental liquids.

Where ilmenite and magnetite are abundant, as in the more evolved gabbros of Units I, II, and VI, and the ferrogabbros of Units III and IV, the sulfides are closely associated with the oxide minerals. These minerals are sufficiently large so that chalcopyrite can be distinguished from pyrite in hand specimen. In these more evolved rocks, pyrite predominates but is usually intergrown with chalcopyrite, again in blebs and globules. Pyrrhotite occurs as well, but in minor abundances and most often forms as small sectors having linear, presumably facet-defined, edges within larger domains of pyrite. Three-phase aggregates of pyrrhotite, pyrite, and chalcopyrite are common. The optical anisotropy of both pyrrhotite and chalcopyrite is not as marked as it is in the olivine gabbros. These observations suggest changes in composition of these phases as temperatures decreased with increasing degree of fractionation (Mathez and Yeats, 1976).

The minor sulfide phases bornite, covellite, and sphalerite also occur in the oxide-rich ferrogabbros. The first two copper-bearing phases occur as rare intergrowths with the major sulfide minerals and are dispersed in the vicinity of major sulfide globules ophitically enclosed, for example, by clinopyroxene. In such cases, these are tiny crystals disseminated along cleavage planes in the host crystal away from the enclosed sulfide globule.

Sphalerite occurs only as complex intergrowths, with pyrite in fairly large globules. It is present only in a few samples, but is quite abundant in those; chalcopyrite does not occur in the intergrowths.

The primary sulfide minerals in Hole 735B gabbros appear to have crystallized in all lithologies cored and to range from troctolite to ferrogabbro. The sulfides shifted from a pyrrhotite-dominated assemblage at higher temperatures to a mainly pyrite-chalcopyrite assemblage at lower temperatures, then possibly to a pyrite-sphalerite assemblage in a few samples at even lower temperatures (Barton and Skinner, 1979). Optical properties suggest that changes also occurred in the compositions of individual phases, particularly those of pyrrhotite and chalcopyrite, as fractionation proceeded.

### Sulfides in Metamorphosed Gabbros

Sulfide minerals also occur in close association with iron-titanium oxides in foliated metagabbros, notably in Units I, II, and VI. However, they are mostly pyrite rather than pyrrhotite. This indicates crystallization or recrystallization at slightly lower temperatures than in most of the igneous associations. This is especially the case in Unit VI, where some samples have coarse primary intergrowths of iron-titanium oxides and sulfides that are partly granulated and recrystallized at their edges. In more deformed samples, textural relations clearly show that the components of the sulfides were mobilized along with those of the oxide minerals and that they invaded the fabric of the metamorphosed gabbros as they were being recrystallized. In general, the recrystallized sulfides conform to shapes defined by neoblasts of clinopyroxene and plagioclase and fill fractures, areas near porphyroclasts, and other types of dilatant structures in the

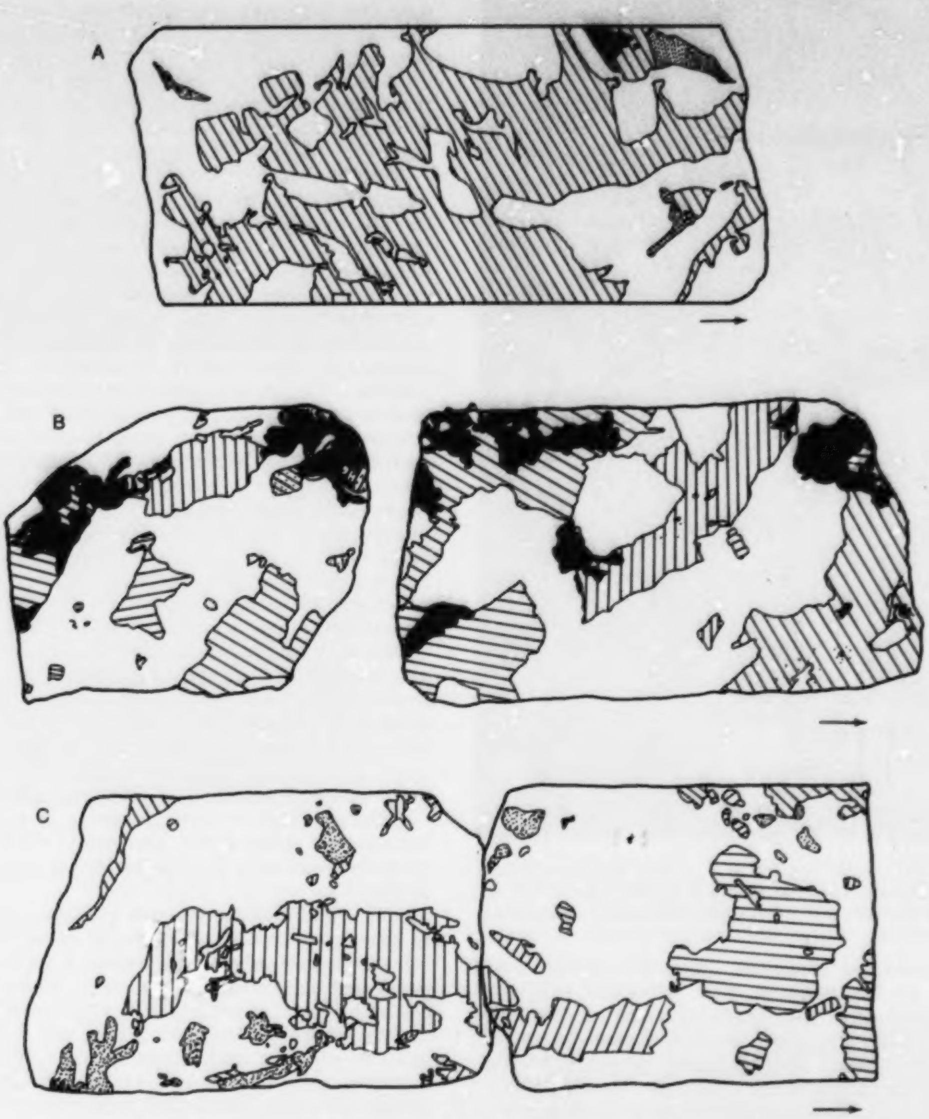

Figure 27. Grain-size tracings of individual pieces. Each slab is 5 cm wide. A. Large clinopyroxene oikocryst (lined) in an olivine gabbro (118-735B-74R-5, 71–85 cm, Piece 3A). Note vertical orientation of the grain. B. Steeply dipping lamination in a coarse-grained iron-titanium oxide gabbro (118-735B-47R-2, 11–41 cm, Pieces 2 and 3). Clinopyroxene is lined, oxides are black, and plagioclase is white. C. Intergranular clinopyroxene in an olivine gabbro (118-735B-87R-1, 10–30 cm, Pieces 3A and 3B). Note the vertical orientation of the large grain; the upper portion of this grain may be a chain of two or three pyroxenes. Clinopyroxene is lined, olivine is dotted, and plagioclase is white.

same manner as the oxide minerals. Contacts with iron-titanium oxides are along straight or curvilinear boundaries that conform to the pattern of ilmenite-magnetite intergrowths.

### Relationships to Silicate Phases

In undeformed gabbros, both iron-titanium oxides and sulfide minerals have obvious primary igneous textures in relation to silicates. That is, they are intergranular in olivine gabbros and troctolites, but locally may be partly or completely enclosed by late-crystallizing ophitic pyroxenes or plagioclase. In ferrogabbros, the iron-titanium oxides are a dominant intercumulus assemblage, and they can both enclose and be enclosed by the magmatic silicates. In the most evolved ferrogabbros, iron-rich olivine occurs, and even this mineral may enclose, or partly enclose, oxide and sulfide phases.

A ubiquitous minor component of all comparatively fresh gabbros, and one closely associated with the oxide and sulfide minerals, is brown amphibole. This mineral is pale brown, pleochroic to clear in olivine gabbros, and darker reddish-brown in the ferrogabbros, where it is also more abundant. In completely

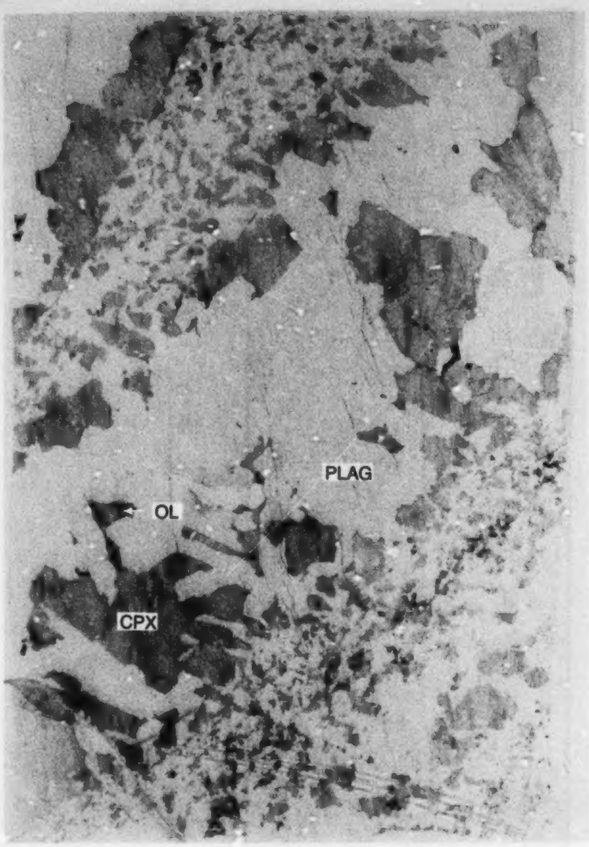

Figure 28. Plane light photograph of 5- × 8-cm thin section showing plagioclase-rich layer in a mixed gabbro-microgabbro interval. Note the orientation of the larger plagioclases and clinopyroxene approximately perpendicular to the layer boundary. Similar thin layers of plagioclase or clinopyroxene occur in some of the coarse-grained portions of size-graded intervals (118-735B-36R-3, 28–34 cm, Piece 1B). OL = olivine; PLAG = plagioclase; CPX = clinopyroxene.

undeformed rocks, it clearly represents late-stage crystallization from intergranular, volatile-rich fluids. These evidently became highly concentrated in the very evolved magmas from which the ferrogabbroic cumulus minerals precipitated.

Brown amphibole of similar appearance occurs in almost every foliated metagabbro, where it is also closely associated with iron-titanium oxides and sulfides. This amphibole crystallized during deformation and recrystallization of the gabbros (see "Metamorphism and Alteration" section, this chapter). In many metagabbros, such amphibole occurs in granulated zones among clinopyroxene neoblasts. It is present without associated iron-titanium oxides in such zones, in rare mylonitized olivine gabbros of Unit V, and with oxide minerals in the more evolved gneissic/porphyroclastic gabbros of Units I, II, and VI.

Where iron-titanium oxides are particularly abundant in shear zones, neoblasts and surrounded porphyroclasts of clinopyroxene and olivine are well preserved, even in specimens where these minerals otherwise were completely replaced by amphibole formed later. Such later amphibole is usually green and is readily distinguished from the brown amphiboles that formed in association with the oxide minerals during deformation. Thus, the oxide minerals evidently formed a nearly impermeable seal, protecting the silicates from later metamorphic transformation to amphibole. In Cores 118-735B-1D through -7D, the only pyroxenes that can be found in some amphibolitized samples occur in the deformation zones, encased in iron-titanium oxides. In one sample, crosscutting fractures are lined with later-formed green amphibole, but these are diverted laterally along the foliation at the main ilmenite-magnetite seam in the rock.

The textural relationships among oxide minerals, neoblasts, porphyroclasts, and brown amphiboles in these highly deformed rocks leaves no doubt about the mobility of iron and titanium during metamorphism. The oxides and associated sulfides tend to fill almost any zone of potential dilatancy that developed in the deforming rocks. They invaded pressure shadows on either side of porphyroclasts; in many zones they filled all space between granular to mylonitic neoblasts; they entered boudinage-type vertical fractures in plagioclase bands in gneissic gabbros; they penetrated partings and cleavage spaces in clinopyroxenes; and they filled temporary fractures formed during deformation that locally crossed the main foliation obliquely, only to become isolated and deformed in turn by later contortions of the plastic rock mass. In no case, however, did the oxide minerals or sulfides replace any porphyroclastic or neoblastic olivine, clinopyroxene, or plagioclase, nor did the interstitial brown amphibole (although a reddish-brown amphibole did form in spaces created during the recrystallization of some clinopyroxene porphyroclasts).

This mobility of components of oxide-sulfide intergrowths, particularly that of titanium, did *not* occur during the later stages of metamorphism experienced by the rocks. Although many rocks were amphibolitized by subsequent metamorphic events, the ilmenite-magnetite intergrowths remained intact, even where isolated grains in a mylonitic matrix could presumably have been readily attacked. In some samples, near fractures where later hydrothermal fluids transformed the rocks to alkali feldspar-epidote-amphibole assemblages, ilmenite is partly or completely converted to sphene, but such occurrences are rare and restricted to narrow brecciated zones. Where later oxidative alteration has occurred, magnetite is altered and largely replaced by clay minerals and iron oxyhydroxides, but ilmenite exsolution lamellae remain.

Only the sulfide minerals were truly susceptible to later metamorphism and alteration. In most samples, they have pitted surfaces, indicating minor selective dissolution. In some rocks, however, sulfides are absent even though ilmenite and some magnetite remain. These rocks are almost wholly transformed to amphibole, and apparently, the reactive fluids involved in the transformation systematically removed sulfides from affected rocks. Occasionally in such rocks, traces of sulfide persist in least-altered cores of clinopyroxene porphyroclasts. But wherever there is pervasive green amphibole, the sulfide minerals are gone. In a few partially amphibolitized rocks, the migration of sulfide components occurred on a restricted scale. In these rocks, tiny pyrite veins can be seen in thin section, sometimes outlining the shapes of granulated neoblasts or partly filling networks of cracks in clinopyroxenes. More prominent secondary pyrite occurs in larger veins that are described in the core logs.

Finally, it is important to note the presence and variable abundance of magnetite in amphibole/talc reaction zones formed during high-temperature static metamorphism of the rocks. The reaction zones can be mere thin borders surrounding olivines and orthopyroxenes, or they can form along cracks within olivines. In a few cases, mafic phases are entirely replaced by clear or pale blue-green amphibole and/or talc. In all these cases, magnetite forms either very tiny or quite substantial crystals, some with vermicular or skeletal outlines. The metamorphism producing these reaction-zone intergrowths affected large parts of the rock, but to variable degrees. This was the principal episode

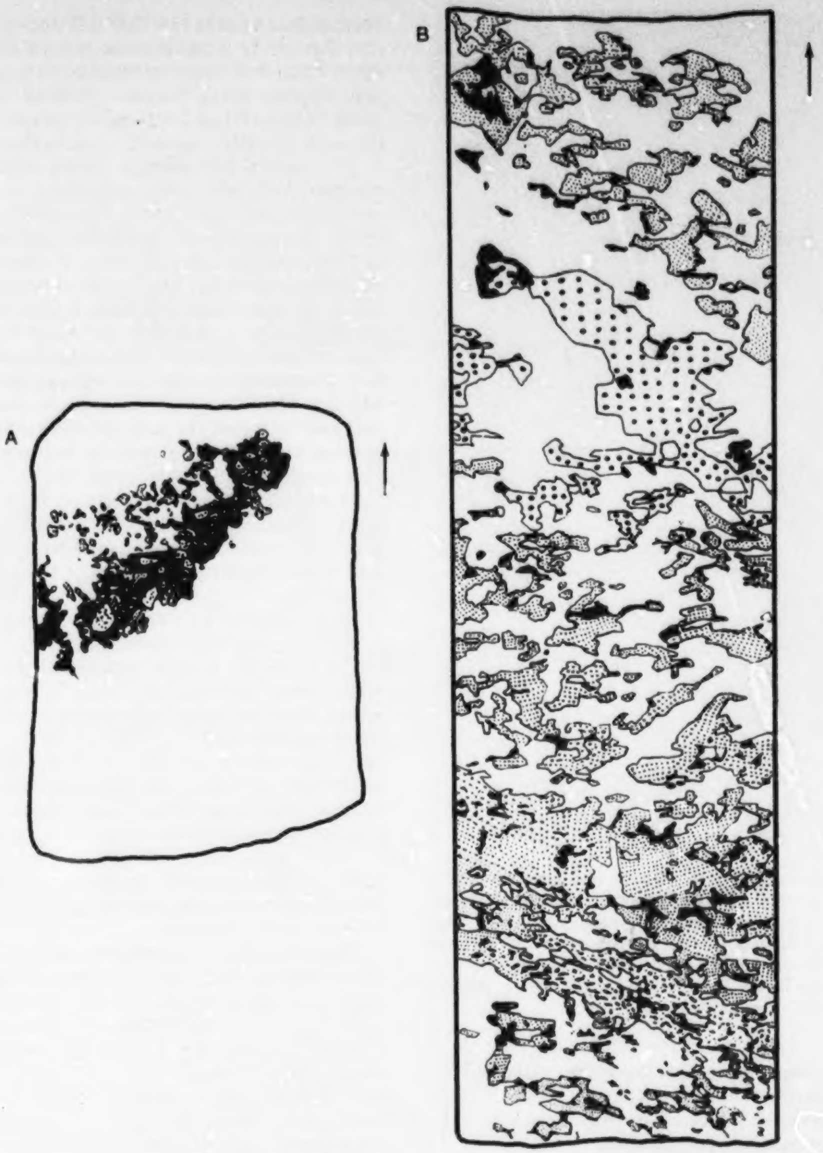

Figure 29. Phase layering in gabbros. Each slab is 5 cm wide. A. Olivine-rich layer (dotted) with poikilitic clinopyroxene (black) in an olivine-bearing, fine- to medium-grained gabbro (white; 118-735B-85R-6, 125–132 cm, Piece 4D). B. Modal layering in an olivine gabbro defined by 1- to 2-cm-thick accumulations of olivine, about 10 cm apart (118-735B-52R-4, 95–125 cm, Piece 4C). Olivine is in large dots, clinopyroxene in fine dots, oxides in black, and plagioclase is white.

of static metamorphism at high temperature that followed the deformation of the rocks. Later, localized hydrothermal alteration caused this magnetite to be removed from some of the rocks, along with their sulfide minerals.

### Summary

From petrographic study, general conclusions are listed as follows.

1. Primary iron-titanium oxides and sulfide minerals are late-crystallizing phases in all undeformed gabbros. Principal minerals are ilmenite, magnetite, pyrrhotite, pyrite, and chalcopyrite.
2. Both iron-titanium oxides and sulfides are more abundant in evolved gabbros than in troctolites and olivine gabbros.
3. Phase proportions of sulfides, and probably their compositions, changed during the course of differentiation as a result of decreasing temperatures. Assemblages shifted from pyrrhotite-dominated to pyrite-dominated as differentiation proceeded.
4. The proportion of total iron-titanium oxides in the gabbros increased with fractionation, from less than that of sulfides to much greater, even though abundances of both oxide minerals and sulfides increased overall.
5. Iron-titanium oxides, sulfides, and brown amphibole are a ubiquitous intergranular and intercumulus mineral assem-

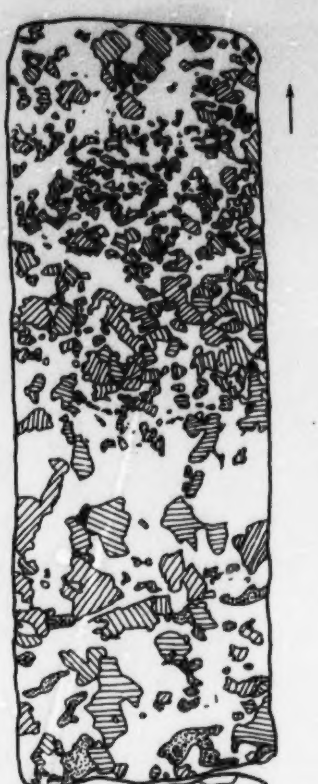

Figure 30. Size grading in an olivine gabbro (118-735B-45R-4, 93–104 cm, Piece 5A) width of slab is 5 cm. Clinopyroxene is lined, olivine is dotted, oxides are black, and plagioclase is white.

blage in undeformed gabbros and in many foliated metagabbros, provided the rocks have not experienced amphibolite-facies metamorphism and hydrothermal alteration. Such metamorphism and alteration stripped sulfides and most magnetite from the affected rocks.

6. The components of the primary opaque mineral assemblage were mobile during the high-temperature plastic deformation that produced the metagabbros and found pathways to migrate along evident porosity structure in a solid-fluid medium.

7. Subsequent static and cataclastic metamorphism produced green-brown, green, pale green, and colorless amphiboles in the gabbros and did not mobilize titanium or greatly modify the ilmenite-magnetite-sulfide intergrowths in either foliated or undeformed gabbros.

8. Fine-grained magnetite formed in reaction zones during a pervasive amphibolite-facies metamorphic event that influenced all the rocks. These are probably the minerals carrying the most stable component of magnetization in the gabbros and metagabbros.

9. Petrographic features suggest that the mobilization of iron-titanium oxides and sulfides took place at high temperatures, probably near the solidus because little apparent difference exists between the oxide-sulfide mineral associations that crystallized during the final stages of consolidation of the gabbros and those in the least-amphibolitized foliated metagabbros. A lower constraint for the temperatures attending deformation is suggested by the occurrence of ilmenite exsolution lamellae in magnetites and of hematite lamellae in ilmenites, as well as the transformation of some ilmenite to sphene. These occurrences all took place at or above 600°C (E. Kikawa, pers. comm., 1987; Miyashiro, 1973) and correspond to the highest-temperature static amphibolite-facies metamorphism that affected most of the rocks. The sulfide plus two-oxide mineral assemblages also indicate that conditions of extreme reduction existed.

## METAMORPHISM AND ALTERATION

### Introduction

Drilling at Site 735 recovered 434.91 m of gabbro and diabase, which were subjected to variable degrees of dynamothermal metamorphism (plastic deformation), followed by nonpervasive brecciation and static alteration associated with brittle deformation and the formation of late vein networks, respectively. The final event was an oxidative alteration that involved the formation of calcite, iron oxyhydroxide, and smectite in discrete horizons. In this section, we summarize the major episodes of metamorphism and alteration, as inferred from recrystallization and replacement of primary mineral assemblages observed in a hand sample to microscopic scale. A summary of deformation events observed on a stratigraphic scale is included in the "Structure and Deformation" section (this chapter).

### Dynamothermal Metamorphism

The gabbroic rocks recovered from Hole 735B have been deformed and recrystallized to variable degrees. The textures observed in the gabbroic rocks grade from medium- to coarse-grained granoblastic to medium- to fine-grained porphyroclastic and mylonitic. To standardize the visual core descriptions and the nomenclature used, the Shipboard Scientific Party subdivided the deformed rocks into five groups that represent increasing intensity of deformation: (1) poorly foliated gabbro, (2) foliated gabbro, (3) porphyroclastic gabbro, (4) augen gneissic gabbro, and (5) mylonitic gabbro.

#### *Textures of Deformed Gabbros*

The poorly foliated gabbros show little recrystallization of the primary phases. Many of these gabbros retain their primary igneous textures (cumulus textures or hypidiomorphic granular and tabular granular, e.g., Samples 118-735B-8D-1, 45–48 cm, Piece 7; 118-735B-18R-3, 29–31 cm, Piece 3; 118-735B-18R-3, 37–40 cm, Piece 4; 118-735B-19R-2, 98–100 cm, Piece 12; 118-735B-29R-4, 19–24 cm, Piece 1B) even though some plagioclase porphyroclasts, granoblasts (crushed crystals), and neoblasts

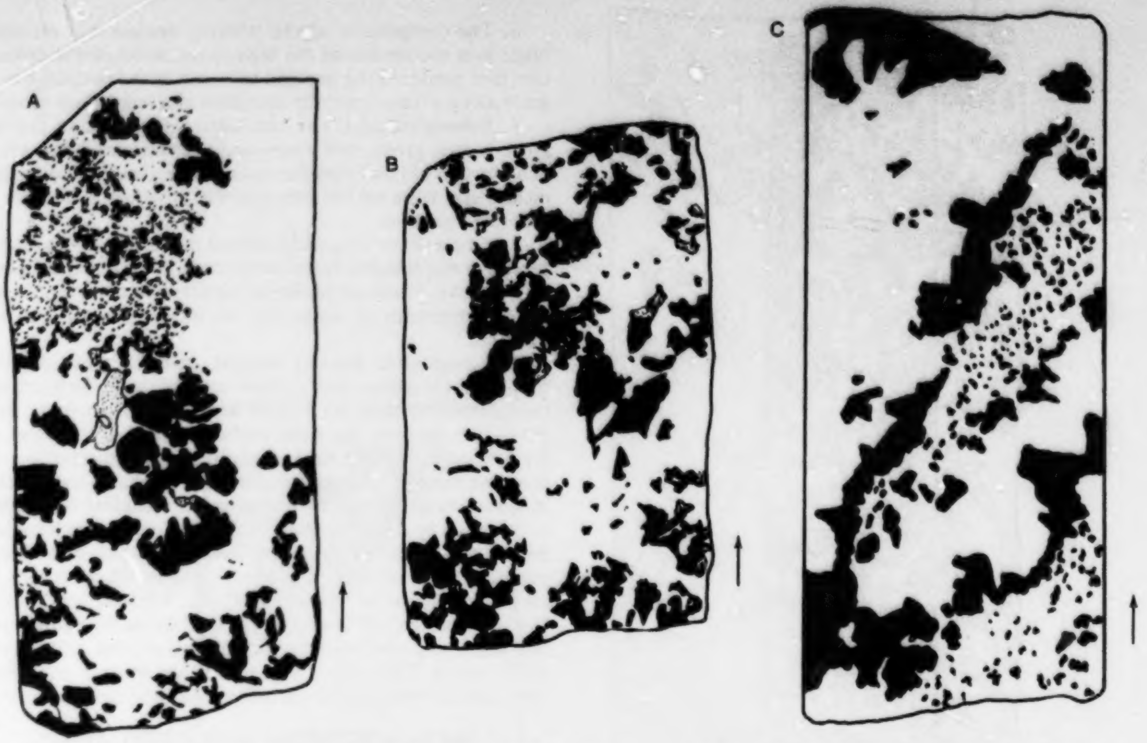

Figure 31. Textural variations in microgabbro. Width of slab is 5 cm. Clinopyroxene in black, olivine is dotted, and plagioclase is white. A. Small, fine-grained layer that may be intrusive (118-735B-45R-3, 55–72 cm, Piece 2A). The large, white area on the right side of the sample is a sheared, amphibolitized zone. B. Small, sandwiched pod of microgabbro (118-735B-76R-3, 74–83 cm, Piece 2F). C. Small, repeated lens of microgabbro (118-735B-36R-3, 28–34 cm, Piece 1B).

(recrystallized crystals) are developed (Fig. 32). The development of layers of continuous foliation distinguishes foliated from poorly foliated textures. A faint foliation results from preferred orientation of the plagioclase and pyroxene crystals. Increasing deformation results in coarse- to fine-grained porphyroclastic textures (e.g., Samples 118-735B-3D-1, 58–60 cm, Piece 11; 118-735B-9D-1, 14–17 cm, Piece 3; 118-735B-20R-2, 10–13 cm, Piece 1C; 118-735B-30R-3, 137–139 cm, Piece 6B).

Examples of poorly foliated, porphyroclastic, augen gneissic, and mylonitic gabbros are provided in Figures 32, 33, 34, and 35, respectively. These are found as isolated bands in poorly foliated to undeformed gabbros (middle section of the hole) as well as within relatively thick sequences of deformed gabbro (upper 40 m of the hole, e.g., Samples 118-735B-2D-1, 113–115 cm, Piece 2; 118-735B-4D-1, 64–68 cm, Piece 10; 118-735B-11D, 1–6 cm, Piece 1). There is a general overall grain-size reduction with increasing intensity of deformation. Grain-size reduction also depends on original texture and grain size of the rocks. The porphyroclasts can be several centimeters wide (1–4 cm) in foliated and porphyroclastic gabbros, but are generally less than 0.5 mm wide in gneissic and mylonitic gabbros. The groundmass surrounding the porphyroclasts ranges from medium- to coarse-grained (0.5–10 mm) in foliated and porphyroclastic gabbros, to fine-grained (<0.5 mm) in mylonitic gabbros. Plagioclase and pyroxene may be segregated into metamorphic bands (Figs. 35 and 36). The banding is rarely well developed in foliated gabbros, but is characteristic of some porphyroclastic gabbros and of most of the gneissic and mylonitic gabbros (Fig. 37). In mylonitic gabbros the foliation is defined by very fine alternating layers (0.4–1 mm thick) of plagioclase and mafic minerals with secondary pyroxene or actinolitic hornblende (e.g., Sample 118-753B-5D-1, 10–13 cm, Piece 3).

Several deformation features related to stress and strain constraints are well developed in the recrystallized textures of the gabbros. The primary phases were deformed at high temperatures under plastic conditions. Olivine shows kink planes, dislocation walls, and subgrain boundaries (e.g., Sample 118-735B-7D-2, 1–5 cm, Piece 1). In mylonitic gabbros, olivine is elongated and up to 6 mm long (e.g., Samples 118-735B-10D-1, 24–26 cm, Piece 6A; 118-735B-10D-2, 18–20 cm, Piece 2; 118-735B-13R-2, 55–58 cm, Piece 4B). Clinopyroxene is deformed and recrystallized into neoblasts (e.g., Samples 118-735B-1D-1, 78–82 cm, Piece 12; 118-735B-8D-1, 45–48 cm, Piece 7; 118-735B-22R-2, 41–43 cm, Piece 1C). The clinopyroxene porphyroclasts are kinked, bent, and elongated, particularly in gneissic and mylonitic gabbros. The augen-type porphyroclasts generally have symmetrical tails of granulated and recrystallized grains produced during grain-reducing mylonitization. They are partially pseudomorphically replaced by brown, yellow-brown, or brownish-green amphiboles (e.g., Samples 118-735B-9D-1, 14–17 cm, Piece 3; 118-735B-22R-2, 41–43 cm, Piece 1C). The pseudomorphic replacement gives a "leopard" texture that results from close intergrowths of amphibole and still fresh or reequilibrated clinopyroxene. The amphibole pseudomorphs are sometimes kinked, which indicates that they are at least partially pre-deformational or syndeformational. The clinopyroxene neoblasts are intergrown (not replaced) with brown or reddish-brown amphibole, which indicates contemporaneous deformation of the two (Fig. 38). The neoblasts of clinopyroxene and amphibole show a polygonal arrangement with straight crystal boundaries and triple junction contacts (e.g., Sample 118-735B-24R-3, 50–52 cm, Piece 3A). Seams of secondary magnetite or ilmenite frequently form on the neoblast boundaries. In mylonitic gabbros, concentrations of neoblasts form flattened lenses

CPX
PLAG
Pn
Pn

Figure 32. Photograph of whole thin section of a poorly foliated gabbro. Plagioclase (PLAG) is already partially recrystallized into neoblasts (Pn). Clinopyroxene (CPX) is only slightly deformed (118-735B-27R-1, 23–25 cm, Piece 5). Scale bar is 1 cm long.

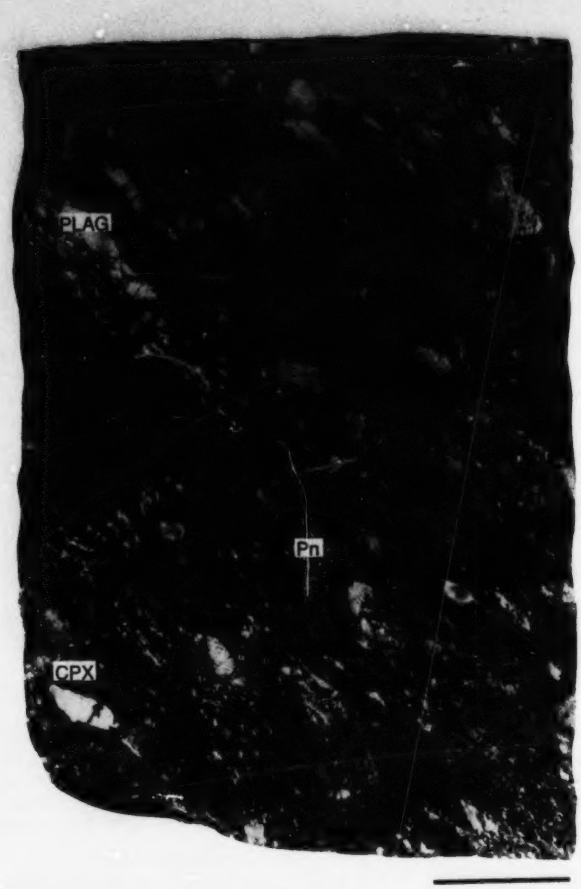

Figure 33. Photograph of whole thin section of a porphyroclastic gabbro showing a strong foliation defined by stretching of plagioclase and clinopyroxene. Plagioclase is highly recystallized into neoblasts. Same legend as in Figure 32 (118-735B-4D-2, 10–16 cm, Piece 1). Scale bar is 1 cm long.

or layers parallel to the foliation. Orthopyroxene occurs as porphyroclasts and augen, more rarely as neoblasts (e.g., Samples 118-735B-3D-1, 46–49 cm, Piece 9; 118-735B-20R-1, 76–80 cm, Piece 14). Orthopyroxene can also be found as exsolution lamellae in clinopyroxene in some mylonitic gabbros (e.g., Sample 118-735B-6D-1, 71–74 cm, Piece 13). Recrystallization of plagioclase is highly variable in all samples. Plagioclase porphyroclasts are strained and show mechanical twin deformation and undulose extinction (Fig. 39). They contain tiny chains of neoblasts running through the crystals (e.g., Sample 118-735B-13R-1, 102–105 cm, Piece 11B). Plagioclase neoblasts are polygonal or irregular in shape and have straight or wavy grain boundaries (Fig. 39). Granoblasts or neoblasts of plagioclase and clinopyroxene form a mosaic groundmass that includes brown amphibole and various amounts of ilmenite and magnetite. Triple-junction contacts were frequently observed (e.g., Samples 118-735B-1D-1, 90–92 cm, Piece 14; 118-735B-24R-3, 50–52 cm, Piece 3A). Ilmenite grains also are deformed and transposed into the foliation. Mechanisms of ilmenite transformation are described at the end of this section.

Brown amphibole occurs in different settings and its significance is discussed in the "Metamorphism" section, Site 733 chapter (this volume). Brown amphibole is always associated with clinopyroxene or occluded ilmenite as patches within the clinopyroxene crystals or at their outermost margins. This type of brown amphibole is strongly pleochroic and limpid under plane light. It may be of primary origin. Brown amphibole of probable secondary origin is preferentially crystallized in microshear zones, cracks, or along cleavages of clinopyroxene. The correlation between the quantity of brown amphibole and the extent of deformation of the gabbro also suggests that the amphibole is secondary. Most of the brown amphibole occurs as granoblasts associated with mosaic groundmass pyroxene and plagioclase neoblasts (e.g., Sample 118-735B-30R-3, 137–139 cm, Piece 6B). Amphibole granoblasts are associated with deformed ilmenite grains in porphyroclastic, gneissic, and mylonitic gabbros. These observations suggest that the brown amphibole is pre-deformational or syndeformational. The association of brown amphibole and deformed, partially replaced pyroxene indicates a maximum temperature of 1050°C (Boyd, 1959; Holloway, 1973) and a minimum temperature of 770°C, according to Spear (1981).

The textural relationships between brown amphibole, clinopyroxene, and ilmenite indicate that crystallization of potential magmatic amphibole occurs near the solidus at a temperature near 900°C, which is consistent with Spear's (1981) experimen-

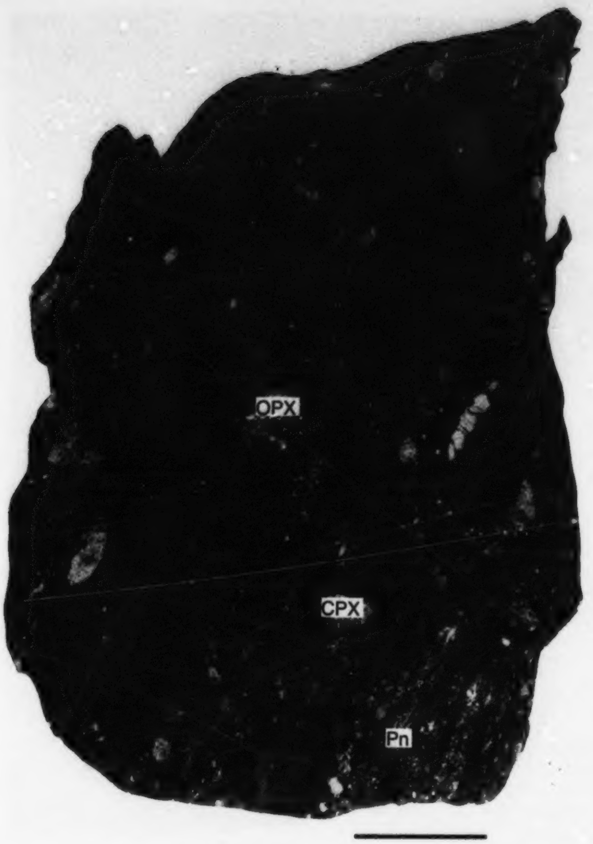

Figure 34. Photograph of whole thin section showing poorly banded augen gneissic gabbro in sharp contact with a very fine-grained mylonitic band. The foliation is enhanced by alternating fine- and coarse-grained bands. Orthopyroxene (OPX) is a coexisting phase. Same legend as Figure 32 (118-735B-1D-2, 80–90 cm, Piece 13). Scale bar is 1 cm long.

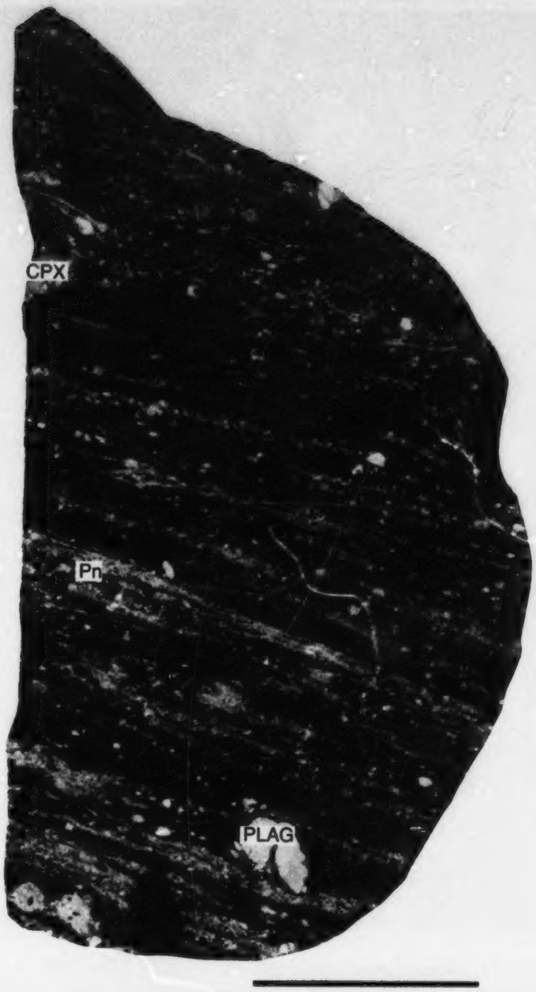

Figure 35. Photograph of a whole thin section of a mylonitic gabbro with well-defined fine-scale banding. Grain size is greatly reduced. Same legend as in Figure 32 (118-735B-3D-1, 44–49 cm, Piece 9). Scale bar is 1 cm long.

tal results and phase relations in the hydrous basaltic system. In addition, the sparse unambiguously igneous brown amphibole and the metamorphic hornblende that increases in quantity with deformation are optically indistinguishable. This, and their association with pyroxene neoblasts, suggest that the formation of the latter may have begun at temperatures over 800°C (Spear, 1981) as the fluids penetrated the gabbroic rocks along grain boundaries. Subsequent amphibole formation probably represents a continuum in compositions associated with declining temperatures and increasing hydration.

These temperatures might be lower, depending on the actual composition of amphibole, a$H_2O$ of the metamorphic fluid, total pressure, and presence of a vapor phase (Spear, 1981; Gilbert et al., 1982). Of these variables, lower a$H_2O$ and fugacity of $H_2O$ are the most critical that might lower the upper stability limit of amphibole by 30° to 100°C.

The high-temperature stage of deformation and metamorphism is overprinted by a second stage of amphibolitization. The amphibole pseudomorphs are partially retrograded into light brown to green hornblende and fibrous green actinolite (e.g., Samples 118-735B-7D-2, 9–11 cm, Piece 1; 118-735B-13R-1, 102–105 cm, Piece 11B; 118-735B-18R-3, 29–31 cm, Piece 3; 118-735B-33R-1, 60-62 cm, Piece 11B) and some chlorite (e.g., Sample 118-735B-15R-1, 90–93 cm, Piece 7B). These late phases are locally deformed in the direction of former foliation or small oblique shear zones. The deformation of medium-grade amphibole is related to a tectonic reactivation of foliation during minor compression-shearing events.

### Ilmenite-Magnetite Concentrations in Deformed Gabbros

Several core intervals contain moderate to high concentrations of ilmenite and magnetite (e.g., Cores 118-735B-44R, -46R, -47R, etc., down to 212 mbsf, particularly in lithologic Units III and IV, see "Lithostratigraphy" section and for detailed descriptions of occurrences, see "Petrography" section, this chapter). These concentrations are layerlike, lens-shaped, or disseminated around silicates. The oxides occur in both massive gabbronorite and variously deformed olivine-bearing and olivine-free gabbro (e.g., Samples 118-735B-44R-2, 6–8 cm, Piece 1A; 118-735B-24R-2, 95–97 cm, Piece 5; 118-735B-53R-3, 15–17 cm, Piece 1B). In massive (undeformed) gabbros, the oxides are large grains that fill intergranular spaces between silicates. They contain small amounts of sulfide minerals. In deformed gabbros, ilmenite and magnetite are granular, recrystallized inter-

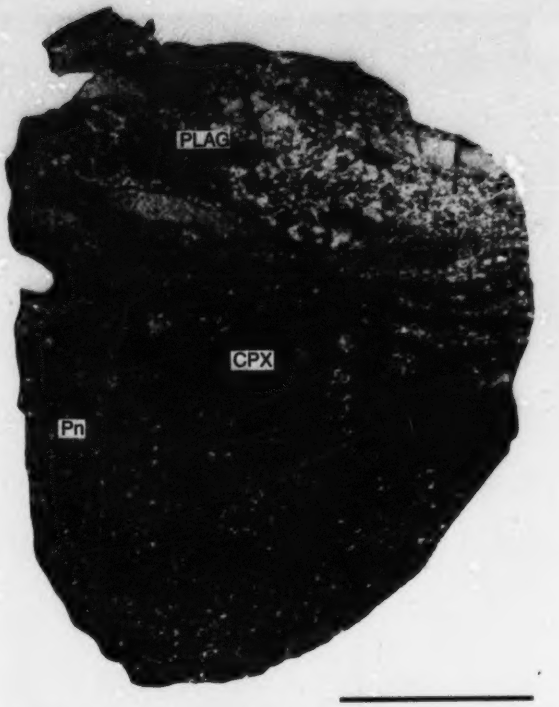

Figure 36. Photography of whole thin section of an augen gneissic gabbro showing wavy plagioclase- and pyroxene-rich alternating bands. Clinopyroxene porphyroclasts are rotated into the foliation. Same legend as in Figure 32 (118-735B-1D-1, 26-30 cm, Piece 4). Scale bar is 1 cm long.

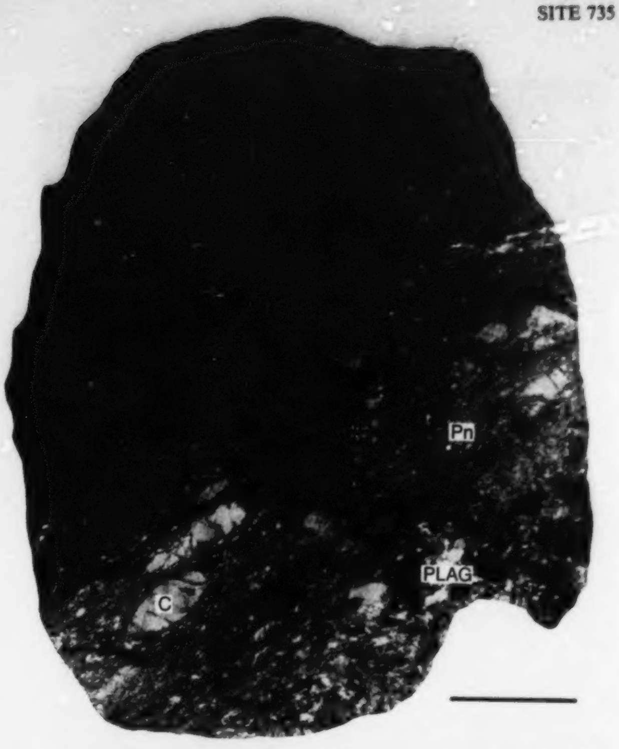

Figure 37. Photograph of a whole thin section of fine-grained porphyroclastic gabbro in sharp contact with a mylonitic band. Clinopyroxene is strongly elongated and plagioclase is present almost solely as neoblasts. Same legend as in Figure 32 (118-735B-4D-2, 24-29 cm, Piece 3). Scale bar is 1 cm long.

growths distributed in the foliation and in open fractures. These oxides are associated with iron-copper and iron sulfides closely mixed with the oxide grains or disseminated into intergranular silicate spaces.

### Ilmenite-Magnetite Characteristics During Stages of Gabbro Deformation

Oxide occurrences in undeformed gabbros thought to reflect primary magmatic processes are typified by Samples 118-735B-23R-3, 34-37 cm, Piece 2; 118-735B-32R-1, 64-66 cm, Piece 1F; 118-735B-44R-4, 6-8 cm, Piece 1A; 118-735B-47R-4, 82-84 cm, Piece 6; and 118-735B-49R-2, 89-91 cm, Piece 1F. In thin sections, primary grain boundary contacts were observed between large undeformed ilmenite grains and clinopyroxene, orthopyroxene, and plagioclase (Fig. 40). Ilmenite is a post-cumulus or late-magmatic phase that poikilitically encloses the silicate minerals. In some cases, spectacular symplectite intergrowths of ilmenite and orthopyroxene were observed. The textural intergrowths are graphic and lamellar (see Fig. 40). Linear inclusions of ilmenite and occasionally rutile as an alteration product of ilmenite, were observed under reflected light (see "Relationship of Sulfides and Oxides to Metamorphism" subsection). In addition, abundant, strongly pleochroic, brown amphibole is intergrown with the ilmenite grains (in the clinopyroxene crystals and the groundmass).

Even though these gabbros are undeformed, the primary phases are partially replaced by metamorphic assemblages (e.g., secondary clinopyroxene and amphibole) and ilmenite shows signs of destabilization. There are coronas of colorless to grass green, fibrous actinolite surrounding ilmenite and clinopyroxene (Fig. 41). Phlogopite also was observed in contact with ilmenite grains (e.g., Section 118-735B-62R-2, 302 mbsf). Irregular granules of magnetite form a discontinuous seam at the very margin of ilmenite within the actinolite coronas and are part of the reaction rim. In turn, primary brown amphibole and actinolite are rimmed by blue-green amphibole. Ilmenite was observed in cracks, along with blue-green amphibole and magnetite assemblages, which suggests remobilization during metamorphism. Vermicular pink sphene, also a metamorphic phase, is spatially associated with the ilmenite grain and was interpreted as a replacement of this phase. Ilmenite mobilization is accentuated where the gabbro is sheared (Fig. 42) or actinolite replacement more advanced. Magnetite is similarly concentrated along the planes of shearing. In crushed areas, there are broken pieces of blue-green and brown amphibole that do not have new metamorphic phases (e.g., Sample 118-735B-22R-1, 78-80 cm, Piece 9).

A second group of samples represents more advanced ilmenite mobility that increases with deformation and metamorphism (e.g., Samples 118-735B-28R-2, 57-60 cm, Piece 6; 118-735B-27R-1, 23-25 cm, Piece 5; 118-735B-48R-4, 82-84 cm, Piece 6; 118-735B-51R-4, 102-104 cm, Piece 1C; 118-735B-52R-4, 69-71 cm, Piece 4B). The host gabbro is deformed and has a porphyroclastic texture. The cores of the clinopyroxene porphyroclasts are fresh and are surrounded by granoblasts of clinopyroxene, brown amphibole, ilmenite, and magnetite. The clinopyroxene neoblasts are inclusion-free and intergrown with neoblasts of both ilmenite and brown amphibole. Granular ilmenite and magnetite are injected into the planes of deformation. The oxides are associated with brown amphibole in all stages of deformation and recrystallization. Where present, cracks are preferentially filled with ilmenite and brown amphibole, along with magnetite granules. Epidote, pink sphene, and actinolite can also be found in open fractures. In this case, ilmenite has been

Figure 38. Photograph of whole thin section of a fine-grained porphyroclastic gabbro showing elongation of pyroxene and plagioclase porphyroclasts and plagioclase neoblasts. An amphibole vein (Av) cuts the porphyroclasts. Same legend as in Figure 32 (118-735B-14R-3, 31-35 cm, Piece 2A). Scale bar is 1 cm long.

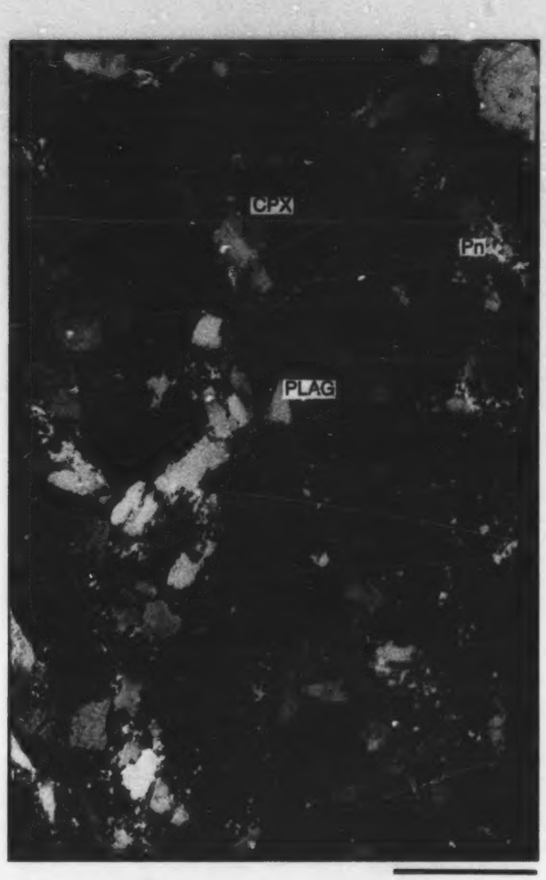

Figure 39. Photograph of whole thin section of a foliated gabbro showing more extensive recrystallization of plagioclase into neoblasts. There is a weak preferred orientation of clinopyroxene and plagioclase. Same legend as in Figure 32 (118-735B-55R-2, 101-105 cm, Piece 4). Scale bar is 1 cm long.

remobilized during actinolite growth in already hydrated rocks at high temperature. The deformation plays an important role in increasing the surface area of grains (recrystallization, crushing) and in creating favorable structures for deposition for mobilized oxides. The metamorphic recrystallization of the igneous clinopyroxene is also a process that may contribute ilmenite to the rock by exclusion of ilmenite inclusions and loss of titanium and iron from enriched clinopyroxene margins or hosted orthopyroxene lamellae.

The third stage of ilmenite destabilization is characterized by development of a strong foliation in the host rock (e.g., Sample 118-735B-53R-3, 15-17 cm, Piece 1B). Like the brown amphibole, ilmenite and magnetite are largely disseminated along the foliation. Intergrowths of ilmenite and brown amphiboles (primary?) were observed in less deformed areas. These assemblages may represent high-temperature igneous assemblages (~900°C). Growth of grass-green amphibole occurred contemporaneously with replacement of igneous calcic plagioclase by sodic plagioclase. Other types of replacement are similar to those in less deformed rocks.

We observed intense transposition of ilmenite-magnetite intergrowths in porphyroclastic gabbros (e.g., Samples 118-735B-24R-2, 95-97 cm, Piece 5; 118-735B-24R-3, 50-52 cm, Piece 3A). The distribution of ilmenite is largely controlled by the well-defined foliation. Again, interstitial granular oxides can be seen in close association with brown amphibole. Both are deformed and recrystallized into granoblasts, forming a mosaic of polygonal grains. We observed plagioclase neoblasts having irregular contacts and rare triple junctions, which indicate a nonequilibrium state. We are not sure whether ilmenite-magnetite intergrowths are *in-situ* recrystallized grains or if they are precipitated phases from hydrothermal fluids. However, the invariable association of oxides with hydrous phases favors the second hypothesis, particularly for the deformed gabbros and for samples where no primary oxide-silicate contacts are preserved.

## Summary

### *Relationship of Sulfides and Oxides to Metamorphism*

Remobilization of ilmenite and magnetite is clearly related to hydration of the gabbroic rocks. The ilmenite first begins to break down at the stage of high-temperature brown amphibole formation. Further breaking down of the oxides during development of green and blue-green amphibole was related to the late vein network (see "Static Alteration in Undeformed Gabbros" section, this chapter) and fluid circulation along the foliation. Clearly, under dynamothermal metamorphism, ilmenite is more extensively altered and remobilized. This remobilization is

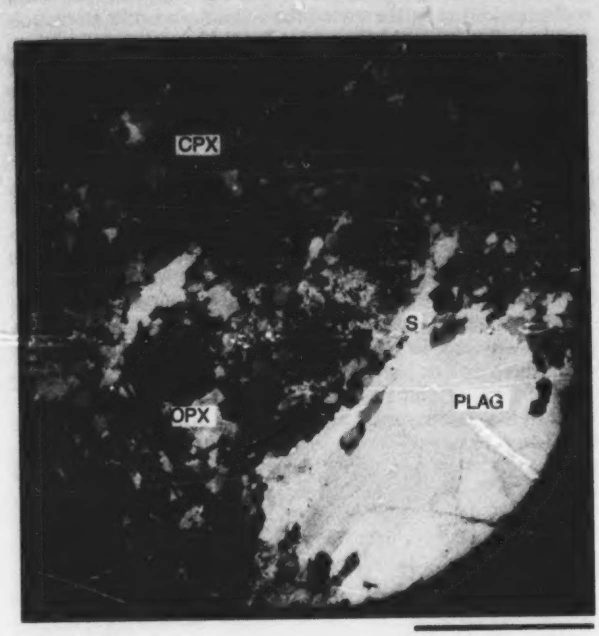

Figure 40. Photograph of whole thin section of primary ilmenite (black) in a poorly foliated orthopyroxene-bearing gabbro. Symplectite relationship between ilmenite and orthopyroxene is visible (S). Ilmenite is a post-cumulus phase. Same legend as in Figure 34 (118-735B-44R-2, 6–8 cm, Piece 1A). Scale bar is 1 cm long.

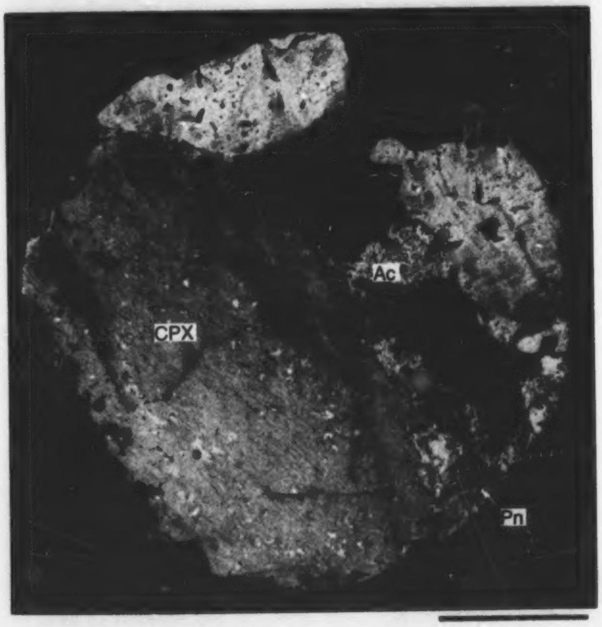

Figure 41. Photograph of whole thin section of a massive ilmenite gabbro showing partial replacement of ilmenite surrounded by coronitic actinolite (Ac). Same legend as in Figure 32 (118-735B-32R-1, 64–66 cm, Piece 1F). Scale bar is 1 cm long.

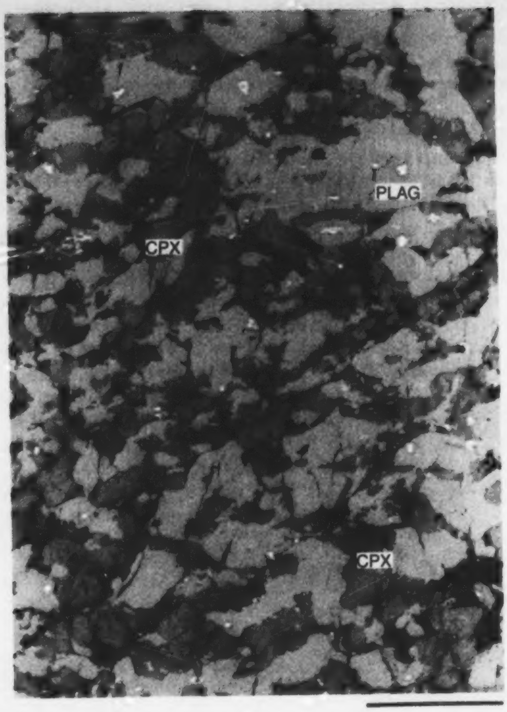

Figure 42. Photograph of whole thin section of a foliated gabbro showing important remobilization of ilmenite-magnetite intergrowths along the foliation and into oblique cracks in plagioclase. Brown amphibole (light gray) is intimately associated with iron oxides. Same legend as in Figure 32 (118-735B-52R-4, 88–94 cm, Piece 4B). Scale bar is 1 cm long.

then amplified in the later hydration stages of medium- to low-grade metamorphism. However, under static metamorphism, the oxides are only partially recrystallized, even at the final stages of hydration. Higher concentrations of iron-copper and iron-sulfides in deformed rocks are consistent with this interpretation. The combined effects of high-temperature deformation (plastic deformation) and hydration (formation of amphibole, micas) are responsible for major alteration of oxides. In addition, recrystallization of clinopyroxene might liberate excess ilmenite. This would add to the quantity of optically identical primary magmatic ilmenite, similar to what was observed for red-brown amphibole under comparable conditions. Ilmenite production may also be mobilized by hydrous fluids at temperatures that prevent the formation of abundant hydrous phases even though $PH_2O$ is elevated. Thus, we wish to stress that under hydrothermal conditions titanium-iron oxides can be considered relatively mobile and capable of being transported in hydrous fluids and deposited in favorable deformation structures. Still unresolved is the question of how far the iron-titanium oxides can be hydrothermally transported. Primary iron-titanium oxide-rich gabbros are known to occur on the ocean floor; generally, these are evolved ferrogabbros (Fox and Stroup, 1981). However, in Hole 735B, the oxide-rich gabbros are often olivine-bearing (e.g., Sample 118-735B-44R-4, 6–8 cm, Piece 1A), which indicates that they originated from a more primitive liquid. The presence of large amounts of iron-titanium oxide in olivine-bearing gabbros suggests a metasomatic origin for the oxides, particularly in the deformed rocks. The assemblage olivine plus abundant ilmenite is very unusual in oceanic crustal rocks.

### Alteration Associated with Cataclastic Deformation

Brittle deformation of the gabbros resulted in formation of predominantly hornblende-bearing veins 0.5 to 2 cm wide. These veins bear a fixed relationship to the orientation of the foliation in the plastically deformed rocks and probably result from the same stress conditions. Secondary alteration associated with crosscutting veins occupies from 1% to 30% of the rock, with an average of about 5%–10%. The vein network provided pathways for fluids to penetrate the gabbros at temperatures low enough to permit the formation of hydrous secondary phases. All alteration that occurred after plastic deformation was related to fractures of variable sizes. Even the smallest percentage of secondary alteration can be related to proximity to microcracks. Movement along some of these fractures is manifested in sheared mineral assemblages within the veins. In addition, zones of brecciation were identified at depths of 180, 260, 270–285, 315, 330, 345, and 500 mbsf. Highly altered pieces of shattered gabbro were recovered from these zones. Miarolitic vein mineralization suggests the existence of open fractures during alteration in these zones. Oxidized halos on pieces of rubble and the replacement of the metamorphic assemblage by carbonate and carbonate veins within these brecciated zones reflect a later lower-temperature alteration under more oxidizing conditions than was observed in nonbrecciated sections of the core.

Within the upper 50 m of the section (Cores 118-735B-1D through 118-735B-14R), the only minerals within the cracks and veins are hornblende and sodic plagioclase. The thin (<0.5 mm) white veins that we observed are submillimeter cracks along which fluids have induced sodium metasomatism. Replacement of the calcic plagioclase by sodic plagioclase is ubiquitous wherever microcracks penetrate the rock. This process is most intense near the fracture systems and almost complete within the brecciated zones. This results in anastomosing networks of milky white sodic plagioclase as rims or complete replacements of the original calcic plagioclase. Clinopyroxene adjacent to these cracks is replaced by dark green hornblende, some of which has euhedral crystal faces projecting into the fracture. In slightly larger veins, hornblende has formed within the fracture as euhedral green laths or fine needles, distinct from the albitized and amphibolitized vein margins. Where shearing has occurred along fractures, the distinction between metasomatic replacement and direct precipitation is difficult to determine. Fragments of sodic plagioclase within such microshears have a crosshatched extinction pattern. We believe this results from almost complete albitization of shattered plagioclase crystals. Only the largest hornblende-sodic plagioclase veins contain blocky grains of untwinned sodic plagioclase that appear to have precipitated directly from metamorphic fluids, rather than forming as a replacement of a preexisting calcic plagioclase. The best example of euhedral metamorphic sodic plagioclase is in the miarolitic veins in the cataclastic breccia (e.g., Sample 118-735B-81R-6, 87–90 cm, Piece 5).

Amphibole veins up to 1.5 cm wide crisscross the foliated metagabbros (Fig. 36), both in the upper part of the section (e.g., Section 118-735B-1D-2, upper 6 m) and in the lowermost foliated gabbros (e.g., Section 118-735B-85R-4 at 475 mbsf). In the upper, intensely foliated section, the green hornblende veins are usually coarsely crystalline. Some are deformed by stretching along the plane of foliation and must predate the last episode of deformation. Most of the hornblende veins in the upper foliated metagabbros, however, and all the veins below the shallow deformation zone (about 75 mbsf) postdate all episodes of plastic deformation. However, these may represent a part of the same deformation event as a late brittle rupturing. In these rocks, as well as in the undeformed units, the vein amphibole occurs as fine-grained laths or needles that may have grown into open cavities as euhedral prisms. The vein hornblende is either green, green-to-brown pleochroic, or, less commonly, brown. Some of the larger veins contain hornblende that is spectacularly zoned from outer green rims to deep brown interiors (Sample 118-735B-12R-1, 65–68 cm, Piece 5B). These veins also contain lesser quantities of green hornblende that is pleochroic to shades of blue-green or turquoise.

The vein amphibole is optically different from the red-brown amphibole that forms neoblasts and intergrowths in the foliated rocks. Where late hornblende veins crosscut foliated metagabbros or mylonites, the clinopyroxene and red-brown hornblende neoblasts are replaced by green-to-brown hornblende of the vein assemblage (Sample 118-735B-7D-1, 63–67 cm, Piece 9). Similarly, clinopyroxene porphyroclasts are replaced by coarse aggregates of green amphibole associated with the late veins (Fig. 43). Some of the clinopyroxene porphyroclasts are replaced by a pale brown hornblende unlike the vein minerals. These latter porphyroclasts sometimes contain relict clinopyroxene cleavage and may have margins replaced by smaller aggregates of green hornblende. This pale brown hornblende may be a syndeformational or pre-(plastic) deformational phase. Extensive amphibolitization and sodium metasomatism are exemplified by Sample 118-735-1D-1, 117–120 cm, Piece 19. In this sample, porphyoclasts

Figure 43. Photograph of a whole thin section of a weakly deformed metagabbro cut by numerous veins of bright green amphibole. Clinopyroxene is partially replaced by the same green amphibole as in the veins. Olivine is replaced by talc plus tremolite plus magnetite with a reaction corona of chlorite extending into the plagioclase (118-735B-15R-3, 92–96 cm, Piece 8). Scale bar is 1 cm long.

of clinopyroxene are pervasively replaced by coarse aggregates of pleochroic brown hornblende. Some of the hornblende crystals are deformed, and the aggregate is rimmed by green hornblende at the boundary with plagioclase. Sodic plagioclase forms an anastomosing network throughout the plagioclase. Only a few neoblasts of clinopyroxene remain; presumably most of them have been replaced by green hornblende.

More extensive alteration of the deformational assemblages (clinopyroxene-plagioclase-orthopyroxene-ilmenite-olivine-red hornblende) results in complex replacement coronas identical to those in the undeformed gabbros. Examples are Samples 118-735B-7D-1, 10-16 cm, Piece 2A; 118-735B-35R-7, 14-17 cm, Piece 2; and 118-735B-37R-1, 11-13 cm, Piece 2A, in which elongate porphyroclasts of orthopyroxene or olivine are replaced by either talc plus acicular amphibole plus magnetite or hematite plus calcite assemblages (Fig. 44). The cummingtonite or anthophyllite in the porphyroclast cores occurs as colorless blades having a fringe of green actinolite. Relict cracks through the porphryoclasts are lined with cummingtonite and opaque grains. The porphyroclasts are surrounded by neoblasts of red-brown hornblende and ilmenite. The red-brown hornblende is partially replaced by actinolite-tremolite. The outermost corona and boundary with plagioclase is composed of pale green pargasite, sometimes intergrown with phlogopite, that extends into the adjacent mosaic of plagioclase (Fig. 45). These samples are crosscut by late veins of green or blue-green hornblende that merge into green amphibole pseudomorphs of clinopyroxene. In foliated samples that have discrete layers of ilmenite, reaction coronas of green hornblende and pleochroic green phlogopite line the boundary between plagioclase and ilmenite (e.g., Sample 118-735B-1D-2, 86-90 cm, Piece 13). Replacement of primary clinopyroxene by amphibole in Cores 118-735B-1D through 118-735B-57R varies from 2%-20%. This *in-situ* replacement, combined with the hornblende within veins (from 0%-30%), brings the total amphibole replacement of gabbro to 10% to 15%.

PLAG
T/M
Tr
Ac

Figure 44. Microphotograph of an olivine pseudomorph with a reaction corona from interval 118-735B-7D-1, 10-16 cm, Piece 2A. The core is replaced by tremolite and talc, with opaque grains of magnetite. The asemblage is itself partially replaced by hematite and calcite. The corona around olivine is (from olivine outward) colorless tremolite (Tr), a skirt of green actinolite, and finally a green talc or mica (T/M) that protrudes into plagioclase. Scale bar is 0.1 mm long. Same legend as in Figures 32 and 41. Plane light.

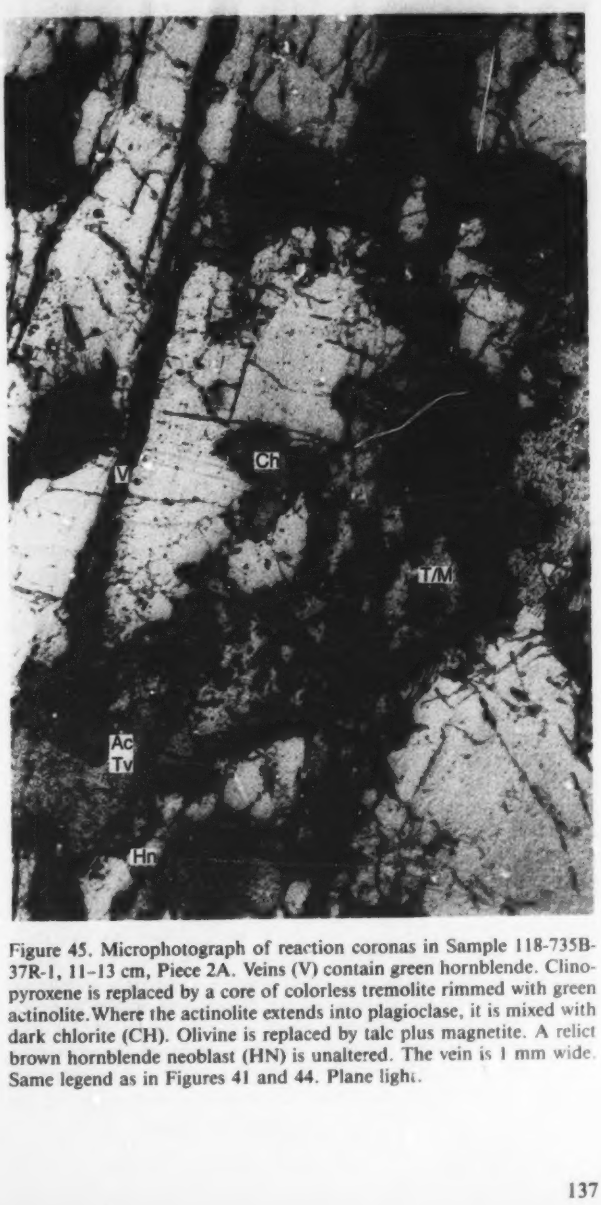

Figure 45. Microphotograph of reaction coronas in Sample 118-735B-37R-1, 11-13 cm, Piece 2A. Veins (V) contain green hornblende. Clinopyroxene is replaced by a core of colorless tremolite rimmed with green actinolite. Where the actinolite extends into plagioclase, it is mixed with dark chlorite (CH). Olivine is replaced by talc plus magnetite. A relict brown hornblende neoblast (HN) is unaltered. The vein is 1 mm wide. Same legend as in Figures 41 and 44. Plane light.

### *Hydrothermal-Plagiogranite Veins*

Small quantities of unusual veins were observed in Cores 118-735B-35R, -43R, -44R, -46R, -64R, and -77R and may be of magmatic or hydothermal origin. A deformed vein in Sample 118-735B-35R-2, 105–106 cm, Piece 4G, contains hornblende, sodic plagioclase, quartz, diopside, phlogopite, and clinozoisite. The hydrothermal vein assemblages are unique and contain either euhedral diopside or hornblende, large (>1 mm) pink, euhedral sphene, yellow rutile, clinozoisite, pistacite, and sodic plagioclase (e.g., Samples 118-735B-68R-3, 62–64 cm, Piece 5 and 118-735B-43R-4, 135–139 cm, Piece 8B), and occasionally carbonate (e.g., Sample 118-735B-77R-1, 33–35 cm, Piece 2C). Similar assemblages replace wall rocks adjacent to these veins (e.g., Sample 118-735B-76R-5, 62–64 cm, Piece 1F). Analcite containing actinolite fibers was observed in veins (Sample 118-735B-19R-2, 98–100 cm, Piece 12) and as rims on plagioclase (Sample 118-735B-45R-4, 136–140 cm, Piece 7). Apatite and euhedral sulfides also were observed in this latter example. In addition, segregated diopside-sodic plagioclase veins up to 1.5 cm wide were observed in cores at about 300 mbsf. Clinozoisite was frequently observed in and below Core 118-735B-18R (below about 70 mbsf). Assemblages observed in altered wall rock below 300 mbsf (e.g., Samples 118-735B-64R-4, 73–76 cm, Piece 1H, and 118-735B-70R-2, 8–10 cm, Piece 2) include green diopside, andesine, clinozoisite, actinolite, sphene, or rutile. Pistacitic epidote and chlorite are abundant only in the largest veins near brecciated zones. Prehnite was optically identified only in a few thin sections, where it combines with tremolite in reaction coronas.

## Static Alteration in Undeformed Gabbros

Alteration in the undeformed gabbros produced reaction coronas around and pseudomorphs of primary igneous minerals. The most abundant hydrous phase is green amphibole, but other secondary minerals include tremolite, talc, clinozoisite, magnetite, chlorite, cummingtonite, pargasite, pinkish sphene, yellow rutile, epidote, and sparse flakes of phlogopite. The quantity and identity of the alteration assemblages were determined by (1) the original permeability that allowed the influx of water, (2) the primary modal abundances, (3) the composition of the primary minerals, and (4) the ambient temperatures existing during the alteration. Olivine and orthopyroxene are preferentially replaced by talc-magnetite ± tremolite ± cummingtonite. The replacement of olivine by talc and magnetite is ubiquitous and apparently occurred at high temperatures with minute quantities of fluid. For example, in one sample, a thin, healed fracture left a subtle alteration scar (where a minute amount of water diffused into the rock) across an otherwise pristine olivine gabbro. Along the fracture, the plagioclase twins are discontinuous, brown hornblende appears as inclusions in clinopyroxene, and a seam of talc and magnetite cuts across a grain of olivine. The proportion of talc increases downhole with the increase of modal olivine, from trace quantities mixed with amphibole to volumes of up to 20% (e.g., Samples 118-735B-16R-5, 24–26 cm, Piece 1B, and 118-735B-20R-1, 29–33 cm, Piece 2B).

Magnesian amphibole (tremolite, anthophyllite, or cummingtonite) also increases in volume with depth, although not as dramatically as talc, because tremolite and actinolite also replace pyroxene throughout the hole. These latter pseudomorphs typically consist of colorless blades of magnesian amphibole at the center with a fringe of bright green actinolite along the boundary with plagioclase. In some of the foliated metagabbros, both porphyroclasts and neoblasts of clinopyroxene, as well as the earlier green to brown hornblende, are replaced by actinolite, which results in layers that completely mask the deformed mafic phases. These layers consist of fine-grained colorless tremolite and green actinolite that extends into the adjacent mosaic of plagioclase.

Plagioclase is replaced along microfractures by sodic plagioclase or by small patches of acicular green amphibole. Plagioclase-olivine boundaries typically are replaced by actinolite (foliated rocks) or by a second outer corona within the plagioclase that consists of pale radial aggregates of pargasite at shallow depths or chlorite at greater depths. Chlorite appears in trace amounts in Core 118-735B-16R and in larger quantities within Core 118-735B-18R, but it is never abundant except locally in veins (e.g., Sample 118-735B-87R-7, 12–15 cm, Piece 1C, a vein in a troctolite). Epidote also appears as a replacement of plagioclase (e.g., Sample 118-725B-18R-3, 29–31 cm, Piece 3), most commonly near veins or brecciated zones.

The spherulitic chlorite that replaces plagioclase along the boundaries with olivine is so dark that in thin section the anomalous blue extinction was difficult to discern. We believe that this reflects a highly magnesian composition. In contrast, chlorite observed along ilmenite-plagioclase boundaries in the oxide-rich gabbros is a very clear green, which probably reflects a high iron content. Small amounts of highly pleochroic, iron-rich, phlogopitic mica were observed as a replacement of ilmenite within the chloritic coronas. In Sample 118-735B-45R-4, 136–140 cm, Piece 7, iron-poor zoisite is joined by a second, more pistacitic, epidote within an iron-titanium oxide-rich zone. The amphibole in the oxide gabbros is similarly bright green and highly pleochroic, which reflects iron-rich compositions. We believe that these iron-rich phases result from the iron-rich protolith (the oxide-rich gabbros), rather than any substantial change in metamorphic conditions.

## Alteration Assemblages in the Cataclastic Zones

Within the cataclastic zones, brecciation of the gabbroic rocks resulted in greater permeability, lower ambient temperatures of alteration, and a greater percentage of replacement by secondary minerals. The high-temperature zoisite or clinozoisite was joined by a true pistacitic green epidote. The dominant amphibole is actinolite, rather than hornblende. Chlorite appears in greatest abundance at these zones, and large pink crystals of sphene replace ilmenite. Extensive albitization of the plagioclase was enhanced by the crushing of plagioclase grains. Silicic clots within these crush zones contain small amounts of quartz.

The distribution of vein assemblages suggests that the predominantly amphibolite to granulite grade conditions that existed for the gabbro declined through a transitional zone to true greenschist grade within the breccia zones. Epidote and chlorite are abundant only within these zones, but prehnite was not observed as a vein mineral. Experimental studies of mineral paragenesis of low-grade metamorphism of basaltic composition (Liou et al., 1985) show that iron-poor epidote and tremolite-actinolite (present in veins outside the breccia zones) are the stable assemblage (over chlorite and prehnite) at temperatures above 400°C at 1 kb. The appearance of green epidote and chlorite in the breccia zones suggests minimum temperatures between 350° to 400°C.

## Oxidative Alteration

One of the unexpected features of Hole 735B was the appearance of oxidized zones, even at substantial depth within the drill hole. It is important to characterize the location and relative timing of oxidative alteration because this may point to zones of permeablity through which cold, oxygenated seawater might circulate. The oxidation, as observed in thin section, produces carbonate-hematite pseudomorphs after olivine and orthopyroxene. Mixtures of smectite and hematite were observed to replace chlorite, plagioclase, or olivine. Some oxidation (<10% clay and hematite replacing orthopyroxene) was observed in the top 26 m of the hole (Cores 118-735B-1D through -6D), but Cores 118-735B-9D and -10D (33-39 mbsf) make up the first major oxidized zone. The surface oxidation declines in Core 118-735B-7D, and the characteristic smectite-carbonate pseudomorphs are replaced by talc-tremolite and small percentages of clinozoisite. The oxidation was interpreted as a late overprint.

The gabbro breccia zones show evidence of significant oxidation, including iron staining and increased abundance of smectite or carbonate. In Core 118-735B-10D, no amphibole veins occur, decreasing albitization is noted, and the late fractures are filled with calcite. Assemblages and textures characteristic of the higher-temperature plastic deformation are sometimes apparent, but more commonly, the brecciated fragments have suffered less plastic deformation. In the brecciated zones at 180, 275, and 330 mbsf, the recovered core consists of shattered fragments coated with orange-brown iron oxide. Here, the orthopyroxene is completely replaced by clots of smectite and hematite and the albite is stained (e.g., Sample 118-735B-9D-1, 120-123 cm, Piece 23). Proximity of the breccia zones to mylonitic zones or magmatic boundaries, (see "Structure and Deformation" section, this chapter) combined with the increased alteration within the zones, suggests that they represent major hydrothermal conduits. In addition, the associated oxidation suggests that permeability may have persisted to allow penetration of lower-temperature fluids.

### Summary

Metamorphism within the rocks from Hole 735B includes dynamothermal, cataclastic, and static alteration. There is no conspicuous variation of metamorphic grade with depth, except perhaps for the appearance of diopside in place of hornblende. Rather, the change in metamorphic grade relates to the distribution of deformation zones and penetration of seawater into cracks and brecciated layers. Dynamothermal alteration occurred at temperatures equivalent to upper amphibolite to granulite grade and produced foliated metagabbros and mylonitic zones. Post-plastic deformation alteration resulted from the penetration of cracks into the gabbros and the development of permeable breccia zones. We are not sure what determines the location of the breccia zones. At 278 mbsf, the breccia zone is adjacent to an impermeable mylonite layer, which suggests a rheological control. At other depths, there may be a geochemical discontinuity, which suggests hydrothermal cracking from diachronous magmatic events. Metamorphism associated with the vertical cracks produced hornblende-sodic plagioclase assemblages at temperatures estimated at 400° to 600°C (Spear, 1980, 1981). Increased circulation within the breccia zones produced lower temperatures of alteration, although the minimum temperature was approximately 350°C (Liou et al., 1985). A late oxidative overprint occurs sporadically throughout the drill hole and is most intense in brecciated zones. Large carbonate veins are associated with these brecciated zones. We believe that this results from renewed circulation of cold oxygenated seawater.

## GEOCHEMISTRY

A total of 97 whole-rock samples from Hole 735B was analyzed using X-ray fluorescence (XRF) for major oxide compositions and abundances of the trace elements vanadium, chromium, nickel, copper, zinc, rubidium, strontium, yttrium, zirconium, and niobium. Sample preparation techniques and analytical procedures are outlined in the "Introduction and Explanatory Notes" (this volume).

The main objective of the sampling strategy was to establish a chemical stratigraphy of the recovered gabbro section. Therefore, care was taken to select from each core at least one sample that was representative of the major part of the drilled sequence. In addition, intervals of macroscopically significantly different lithologies were sampled whenever we thought it necessary. As a rule, the freshest possible material was selected to reduce the effects of alteration on the chemical data. In a few cases, strongly altered samples were taken adjacent to the fresher intervals to gain a first estimate of the effects of chemical redistribution processes.

To minimize the problem of representative sampling of plutonic rocks, most of the chemical analyses were performed on medium- to fine-grained core intervals. Samples were prepared either from slabs used for large thin sections or from minicores used for measuring paleomagnetic and physical properties. Sample sizes generally ranged from 35 to 55 g. All samples were ground in an agate mill.

In most cases, totals of shipboard XRF major elemental oxides were between 99.2% and 100.8%. The deviations from 100% result essentially from counting statistics and from weighing errors that affect all components to the same extent. The analysis of duplicate glass beads showed that a few anomalously large deviations (98%-103%) might be attributed to weighing problems in the shipboard environment. To overcome these weighing problems, all measured values were normalized to a sum of 100%.

The loss-on-ignition (LOI) values provide only limited information on the amount of bound water (and/or $CO_2$) in the rocks because the loss of weight from removing volatiles is counterbalanced by oxidation of the ferrous iron. Actually, many of the iron-rich rocks analyzed have positive LOI values because of this effect.

Shipboard data for major elements were supplemented with post-cruise data for $H_2O$ and $CO_2$ contents and for ferrous/ferric iron ratios. The analyses were performed on powdered samples prepared on board the ship and were conducted at Giessen and Leuven Universities using standard analytical methods. The major element data are listed in Table 4. All components are normalized to a sum of 100%. Shipboard XRF analyses of ignited samples were recast to actual rock compositions using the shore-based FeO, $H_2O$, and $CO_2$ data.

The obtained trace-element abundances were determined from pressed powder pellets prepared from dried, i.e., not ignited, material (Table 4). Except for rubidium and niobium, the observed abundances are well above the respective detection limits, so that the analytical errors summarized in the "Introduction and Explanatory Notes" (this volume) apply. The measured contents of rubidium and niobium in many cases are below the detection limits of 0.8 and 0.5 ppm, respectively. Values close to the detection limits should be used with care because they are affected by relative large errors (on the order of 50% relative).

In addition to the standard sample designations (core, section, section interval in centimeters, piece number), each sample was tagged by the nominal depth in meters below seafloor (mbsf) and given a rock type code. The latter was used to provide concise information about petrography, metamorphism, and deformation of the rocks. The type abbreviations are explained in a footnote to Table 4.

According to this simplified classification scheme, the spectrum of analyzed rocks covers:

42 olivine gabbros (olivine content >5 vol%),
14 olivine-bearing gabbros (4 of them foliated and metamorphosed),
5 gabbros,
15 metagabbros (14 of them deformed),
2 gabbronorites (1 deformed),
3 microgabbros,
8 iron-titanium oxide gabbros (5 of them olivine-bearing),
4 troctolites,
1 basalt dike, and
1 trondjhemite (small dike).

**Table 4. Chemical composition of rock samples from Hole 735B.**

| Core/section: | 1D-1 | 1D-1 | 1D-2 | 2D-1 | 2D-2 | 3D-1 | 4D-2 | 6D-1 | 7D-1 | 7D-2 | 10D-1 | 12R-1 | 13R-1 | 14R-3 | 15R-1 | 15R-3 | 16R-1 | 17R-1 | 18R-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 90–98 | 117–120 | 91–94 | 76–80 | 116–120 | 46–49 | 10–16 | 71–74 | 63–67 | 1–5 | 46–49 | 118–123 | 102–105 | 136–141 | 90–93 | 92–96 | 139–141 | 22–27 | 143–146 |
| Piece: | 14 | 19 | 14 | 14 | 19B | 9 | 1 | 13 | 9 | 1 | 8 | 11 | 11B | 10 | 7B | 8 | 3H | 5 | 17 |
| Mbsf[1]: | 0.9 | 1.2 | 2.4 | 7.3 | 9.2 | 15.0 | 19.1 | 24.7 | 26.6 | 27.5 | 36.7 | 40.6 | 45.5 | 55.1 | 57.1 | 60.1 | 63.2 | 67.2 | 71.4 |
| Unit[2]: | I | I | I | I | I | I | I | I | I | I | I | II | II | II | II | II | II | II | II |
| Type[3]: | MGD | MGD | MGD | MGD | MGD | MGD | GND | MGD | MGD | MGD | MGD | GO | GOD | GO | MGD | G | MGD | GO | MGD |
| $SiO_2$ | 51.66 | 54.21 | 51.87 | 51.35 | 51.17 | 53.93 | 52.69 | 49.97 | 49.28 | 49.28 | 52.64 | 50.73 | 50.34 | 51.71 | 51.40 | 50.25 | 51.56 | 50.74 | 50.58 |
| $TiO_2$ | 0.85 | 0.56 | 0.84 | 0.42 | 0.37 | 0.55 | 0.33 | 1.78 | 0.26 | 0.25 | 0.62 | 0.23 | 0.32 | 0.38 | 0.60 | 0.44 | 1.13 | 0.56 | 0.37 |
| $Al_2O_3$ | 14.90 | 20.93 | 15.01 | 16.93 | 19.24 | 15.64 | 16.30 | 14.65 | 14.92 | 15.13 | 14.97 | 20.49 | 16.04 | 17.20 | 16.39 | 14.06 | 16.56 | 15.34 | 13.65 |
| $Fe_2O_3$ | 2.05 | 1.15 | 1.91 | 1.85 | 2.71 | 1.64 | 2.96 | 2.15 | 2.53 | 1.91 | 2.19 | 0.57 | 1.34 | 1.10 | 1.44 | 1.55 | 1.37 | 1.23 | 0.97 |
| FeO | 6.64 | 3.80 | 6.74 | 6.52 | 4.34 | 5.96 | 5.51 | 7.06 | 3.88 | 4.52 | 6.19 | 3.74 | 4.89 | 4.42 | 6.12 | 6.27 | 5.85 | 5.91 | 4.61 |
| MnO | 0.17 | 0.10 | 0.16 | 0.17 | 0.13 | 0.16 | 0.20 | 0.19 | 0.13 | 0.12 | 0.19 | 0.11 | 0.12 | 0.11 | 0.12 | 0.13 | 0.10 | 0.13 | 0.10 |
| MgO | 6.98 | 3.82 | 6.89 | 8.39 | 6.78 | 8.05 | 8.03 | 7.56 | 12.92 | 12.30 | 7.80 | 6.42 | 10.57 | 7.95 | 8.54 | 10.94 | 7.67 | 10.37 | 12.20 |
| CaO | 11.98 | 9.64 | 11.99 | 9.66 | 10.41 | 11.07 | 8.15 | 11.61 | 12.65 | 12.41 | 11.13 | 13.53 | 12.90 | 13.04 | 10.93 | 12.58 | 10.86 | 11.76 | 14.36 |
| $Na_2O$ | 3.40 | 5.19 | 3.46 | 3.30 | 3.62 | 3.53 | 4.00 | 3.48 | 2.03 | 2.39 | 3.14 | 2.98 | 2.49 | 2.99 | 3.37 | 2.44 | 3.73 | 2.64 | 1.69 |
| $K_2O$ | 0.16 | 0.09 | 0.16 | 0.25 | 0.12 | 0.16 | 0.13 | 0.11 | 0.12 | 0.14 | 0.12 | 0.07 | 0.04 | 0.04 | 0.07 | 0.07 | 0.07 | 0.08 | 0.05 |
| $P_2O_5$ | 0.02 | 0.02 | 0.03 | 0.04 | 0.07 | 0.07 | 0.13 | 0.54 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 | 0.04 | 0.02 | 0.20 | 0.04 | 0.01 |
| $H_2O$ | 1.17 | 0.43 | 0.94 | 1.13 | 0.79 | 1.24 | 1.27 | 0.80 | 1.21 | 1.24 | 1.04 | 1.08 | 0.71 | 0.75 | 0.98 | 1.09 | 0.93 | 1.22 | 1.48 |
| $CO_2$ | 0.07 | 0.09 | [6]nd | nd | 0.24 | nd | 0.34 | nd | nd | 0.28 | nd | 0.07 | 0.26 | 0.31 | nd | 0.19 | nd | nd | nd |
| [4]LOI | 1.01 | 0.29 | 0.73 | 0.72 | 1.11 | 1.05 | 1.25 | 0.71 | 1.63 | 1.00 | 0.76 | 1.11 | 0.77 | 0.73 | 0.88 | 0.79 | 0.86 | 1.08 | 1.70 |
| V | 243 | 152 | 254 | 128 | 90 | 165 | 88 | 210 | 127 | 124 | 238 | 94 | 131 | 171 | 179 | 173 | 169 | 122 | 182 |
| Cr | 9 | 1 | 8 | 8 | 8 | 18 | 4 | 168 | 605 | 328 | 35 | 441 | 360 | 76 | 72 | 308 | 36 | 854 | 795 |
| Ni | 32 | 16 | 30 | 53 | 48 | 51 | 89 | 82 | 165 | 172 | 50 | 71 | 121 | 59 | 68 | 122 | 76 | 179 | 211 |
| Cu | 42 | 9 | 42 | 25 | 22 | 22 | 18 | 61 | 35 | 20 | 68 | 16 | 39 | 18 | 12 | 12 | 9 | 55 | 12 |
| Zn | 60 | 35 | 62 | 56 | 42 | 56 | 45 | 52 | 28 | 35 | 58 | 35 | 38 | 27 | 31 | 27 | 17 | 40 | 26 |
| Rb | 3.3 | <0.8 | 3.2 | 3.0 | 0.8 | 1.8 | 1.4 | 1.1 | <0.8 | <0.8 | 1.5 | <0.8 | 1.0 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 |
| Sr | 157 | 259 | 158 | 176 | 220 | 157 | 199 | 162 | 141 | 125 | 170 | 194 | 159 | 175 | 163 | 134 | 187 | 153 | 111 |
| Y | 19 | 11 | 21 | 12 | 7 | 36 | 28 | 51 | 9 | 12 | 17 | 8 | 12 | 14 | 28 | 14 | 41 | 31 | 12 |
| Zr | 26 | 17 | 27 | 26 | 15 | 37 | 969 | 136 | 8.3 | 24 | 39 | 12.1 | 25.2 | 18.7 | 110 | 23.9 | 187 | 89 | 15.9 |
| Nb | 0.7 | <0.5 | 0.5 | 0.6 | 0.6 | 2.4 | 1.3 | 3.9 | <0.5 | <0.5 | <0.5 | <0.5 | 0.6 | <0.5 | 1.2 | <0.5 | 2.1 | 1.8 | <0.5 |
| [5]Mg# | 0.63 | 0.62 | 0.63 | 0.68 | 0.68 | 0.69 | 0.67 | 0.63 | 0.81 | 0.80 | 0.66 | 0.87 | 0.78 | 0.75 | 0.71 | 0.75 | 0.69 | 0.75 | 0.82 |
| $MgO/Al_2O_3$ | 0.47 | 0.18 | 0.46 | 0.50 | 0.35 | 0.51 | 0.49 | 0.52 | 0.87 | 0.81 | 0.52 | 0.31 | 0.66 | 0.46 | 0.52 | 0.78 | 0.46 | 0.68 | 0.89 |
| $CaO/Al_2O_3$ | 0.80 | 0.47 | 0.80 | 0.57 | 0.54 | 0.71 | 0.50 | 0.79 | 0.85 | 0.82 | 0.74 | 0.66 | 0.80 | 0.76 | 0.67 | 0.89 | 0.66 | 0.77 | 1.05 |
| $CaO/Na_2O$ | 3.52 | 1.86 | 3.46 | 2.93 | 2.88 | 3.14 | 2.04 | 3.19 | 6.22 | 5.19 | 3.55 | 4.54 | 5.18 | 4.36 | 3.24 | 5.16 | 2.91 | 4.46 | 8.48 |

[1] Mbsf = meters below seafloor.

[2] Unit = lithologic unit.

[3] G = gabbro; GN = gabbronorite; OG = olivine gabbro; GO = gabbro, olivine-bearing; FG = Fe-Ti-oxide gabbro; FGO = Fe-Ti-oxide gabbro, olivine-bearing; MIG = microgabbro; MG = metagabbro; MGO = metagabbro, olivine-bearing; TR = troctolite; TJ = trondhjemite; BD = basalt dike; D at the end = deformed (e.g., MGD = deformed metagabbro).

[4] LOI = weight loss on ignition: values preceded with + sign denote gain in weight on ignition.

[5] Mg# = molar ratio (Mg/Mg + 0.86Fe$_{(tot)}$).

[6] nd = not determined.

**Table 4 (continued).**

| Core/section: | 18R-3 | 19R-3 | 20R-2 | 21R-2 | 22R-2 | 23R-2 | 23R-2 | 23R-4 | 24R-4 | 25R-1 | 25R-3 | 25R-3 | 26R-1 | 26R-4 | 27R-3 | 28R-3 | 29R-3 | 30R-1 | 30R-5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 37–40 | 73–75 | 23–27 | 53–56 | 86–91 | 42–48 | 66–73 | 83–86 | 1–6 | 21–25 | 43–48 | 144–146 | 131–134 | 91–92 | 73–81 | 63–69 | 124–130 | 135–138 | 110–115 |
| Piece: | 4 | 6A | 2 | 1B | 3B | 1C | 1D | 5 | 1A | 5 | 2B | 3B | 6A | 5 | 1D | 4 | 14C | 18 | 7 |
| Mbsf[1]: | 71.9 | 78.3 | 85.8 | 90.7 | 96.4 | 101.6 | 101.8 | 104.8 | 109.8 | 110.7 | 113.7 | 114.7 | 116.8 | 120.9 | 125.2 | 130.1 | 135.6 | 137.9 | 143.5 |
| Unit[2]: | II | II | II | II | II | II | II | II | II | II | II | II | II | II | II | II | II | II | II |
| Type[3]: | MIG | GO | GOD | OG | OG | MIG | OG | BD | G | MG | OG | OG | OG | G | OG | GN | OG | MGO | GO |
| $SiO_2$ | 48.00 | 51.07 | 41.03 | 52.06 | 49.23 | 46.44 | 50.71 | 49.71 | 50.60 | 49.97 | 50.48 | 48.30 | 49.82 | 51.74 | 50.27 | 51.88 | 49.93 | 51.67 | 53.13 |
| $TiO_2$ | 0.19 | 0.32 | 0.39 | 0.31 | 0.52 | 4.84 | 0.31 | 1.67 | 0.24 | 0.93 | 0.26 | 0.21 | 0.27 | 0.25 | 0.40 | 1.13 | 0.26 | 0.48 | 0.49 |
| $Al_2O_3$ | 17.32 | 18.47 | 5.01 | 19.60 | 9.26 | 12.96 | 18.81 | 15.17 | 19.08 | 14.08 | 17.86 | 16.01 | 15.70 | 22.90 | 14.08 | 11.66 | 17.78 | 15.78 | 17.22 |
| $Fe_2O_3$ | 1.42 | 0.83 | 5.45 | 3.77 | 0.64 | 2.13 | 0.80 | 2.61 | 0.52 | 2.31 | 0.43 | 0.80 | 0.59 | 0.14 | 0.59 | 3.00 | 0.93 | 1.41 | 1.09 |
| FeO | 4.86 | 3.52 | 19.62 | 0.00 | 6.91 | 11.13 | 4.07 | 7.29 | 4.21 | 7.91 | 3.97 | 4.93 | 4.18 | 2.67 | 4.83 | 11.19 | 4.00 | 6.28 | 6.47 |
| MnO | 0.09 | 0.09 | 0.41 | 0.08 | 0.16 | 0.19 | 0.09 | 0.19 | 0.09 | 0.11 | 0.09 | 0.12 | 0.11 | 0.06 | 0.12 | 0.33 | 0.10 | 0.14 | 0.15 |
| MgO | 11.71 | 8.46 | 22.01 | 7.03 | 16.98 | 8.05 | 8.80 | 7.96 | 9.19 | 9.54 | 10.22 | 13.85 | 11.90 | 4.92 | 12.14 | 9.88 | 10.04 | 8.47 | 6.55 |
| CaO | 11.34 | 13.26 | 4.50 | 14.19 | 14.26 | 9.78 | 12.71 | 10.91 | 12.51 | 11.18 | 13.65 | 12.67 | 14.22 | 13.14 | 14.92 | 7.14 | 13.32 | 10.84 | 10.30 |
| $Na_2O$ | 2.46 | 2.82 | 0.71 | 2.94 | 1.21 | 3.25 | 2.73 | 2.53 | 2.87 | 2.91 | 2.37 | 2.11 | 1.91 | 3.36 | 1.98 | 2.91 | 2.47 | 3.43 | 4.01 |
| $K_2O$ | 0.18 | 0.03 | 0.12 | 0.03 | 0.02 | 0.19 | 0.06 | 0.05 | 0.06 | 0.11 | 0.02 | 0.07 | 0.04 | 0.04 | 0.02 | 0.05 | 0.05 | 0.03 | 0.07 |
| $P_2O_5$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.17 | 0.06 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.05 | 0.00 | 0.00 | 0.04 |
| $H_2O$ | 2.25 | 1.12 | 0.74 | 0.00 | 0.82 | 0.91 | 0.94 | 1.76 | 0.64 | 0.94 | 0.54 | 1.01 | 1.26 | 0.63 | 0.53 | 0.78 | 1.12 | 1.48 | 0.51 |
| $CO_2$ | 0.19 | nd | nd | nd | nd | 0.15 | nd | nd | nd | nd | 0.11 | nd | nd | 0.15 | 0.13 | nd | nd | nd | nd |
| [4]LOI | 2.25 | 1.00 | +0.11 | 0.97 | 0.27 | 0.10 | 0.78 | 1.71 | 0.52 | 1.02 | 0.35 | 0.89 | 0.51 | 0.56 | 0.60 | 0.20 | 1.35 | 1.57 | 0.23 |
| V | 76 | 117 | 102 | 124 | 219 | 842 | 118 | 273 | 88 | 541 | 122 | 92 | 130 | 81 | 185 | 165 | 116 | 224 | 155 |
| Cr | 327 | 148 | 96 | 165 | 324 | 24 | 134 | 212 | 251 | 221 | 368 | 383 | 459 | 180 | 633 | 2 | 327 | 49 | 24 |
| Ni | 233 | 92 | 318 | 79 | 172 | 82 | 97 | 99 | 113 | 128 | 125 | 220 | 171 | 62 | 145 | 34 | 117 | 47 | 52 |
| Cu | 5.0 | 12 | 93 | 10 | 63 | 32 | 10 | 61 | 15 | 9 | 21 | 103 | 43 | 9 | 70 | 44 | 11 | 9.0 | 79 |
| Zn | 17 | 21 | 128 | 18 | 48 | 52 | 24 | 84 | 22 | 17 | 23 | 35 | 29 | 17 | 32 | 117 | 25 | 30 | 47 |
| Rb | <0.8 | <0.8 | 2.2 | <0.8 | <0.8 | <0.8 | <0.8 | 0.9 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 |
| Sr | 157 | 177 | 47 | 185 | 84 | 120 | 176 | 152 | 172 | 134 | 162 | 145 | 135 | 214 | 125 | 153 | 159 | 168 | 204 |
| Y | 5 | 8 | 11 | 8 | 15 | 34 | 8 | 34 | 7 | 18 | 6 | 6 | 7 | 6 | 12 | 19 | 8 | 13 | 17 |
| Zr | 11.8 | 18.6 | 18.3 | 15.5 | 27.1 | 29.1 | 11.6 | 131 | 13.2 | 19.8 | 6.5 | 4.5 | 9.7 | 9.2 | 14.5 | 27.8 | 7.3 | 12.9 | 41.9 |
| Nb | <0.5 | <0.5 | 2.8 | <0.5 | <0.5 | 2.3 | <0.5 | 3.4 | 0.5 | 1.1 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 1.2 | <0.5 | <0.5 | <0.5 |
| [5]Mg# | 0.80 | 0.80 | 0.65 | 0.81 | 0.83 | 0.56 | 0.79 | 0.63 | 0.80 | 0.66 | 0.83 | 0.84 | 0.84 | 0.79 | 0.82 | 0.60 | 0.81 | 0.70 | 0.65 |
| $MgO/Al_2O_3$ | 0.68 | 0.46 | 4.39 | 0.36 | 1.83 | 0.62 | 0.47 | 0.52 | 0.48 | 0.68 | 0.57 | 0.87 | 0.76 | 0.21 | 0.86 | 0.85 | 0.56 | 0.54 | 0.38 |
| $CaO/Al_2O_3$ | 0.65 | 0.72 | 0.90 | 0.72 | 1.54 | 0.75 | 0.68 | 0.72 | 0.66 | 0.79 | 0.76 | 0.79 | 0.91 | 0.57 | 1.06 | 0.61 | 0.75 | 0.69 | 0.60 |
| $CaO/Na_2O$ | 4.61 | 4.70 | 6.34 | 4.83 | 11.79 | 3.01 | 4.66 | 4.32 | 4.37 | 3.85 | 5.76 | 6.00 | 7.42 | 3.91 | 7.55 | 2.45 | 5.39 | 3.16 | 2.57 |

Table 4 (continued).

| Core/section: | 31R-2 | 31R-2 | 32R-3 | 32R-4 | 33R-3 | 33R-4 | 34R-2 | 35R-4 | 36R-2 | 36R-4 | 37R-3 | 38R-2 | 39R-1 | 40R-4 | 41R-4 | 42R-3 | 43R-1 | 44R-2 | 44R-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 40–45 | 77–81 | 54–60 | 43–49 | 85–89 | 27–29 | 18–22 | 43–46 | 98–102 | 30–33 | 80–82 | 78–84 | 145–147 | 1–5 | 22–27 | 9–14 | 22–29 | 6–8 | 78–81 |
| Piece: | 2B | 3C | 1E | 1E | 7 | 2B | 1C | 2A | 1E | 1B | 4 | 4B | 3B | 1A | 1A | 1B | 1B | 1A | 5D |
| Mbsf[1]: | 145.4 | 145.8 | 151.7 | 152.5 | 157.3 | 158.1 | 160.0 | 168.3 | 173.5 | 175.1 | 179.6 | 183.3 | 187.5 | 194.4 | 200.4 | 204.0 | 206.2 | 212.3 | 214.4 |
| Unit[2]: | II | II | II | II | II | II | II | II | II | II | II | III | III | III | III | III | III | III | III |
| Type[3]: | OG | MGD | OG | OG | GO | GOD | OG | OG | GO | G | G | OG | OG | MIG | OG | GO | GO | FG | OG |
| $SiO_2$ | 51.47 | 48.91 | 53.00 | 51.35 | 51.56 | 53.90 | 49.96 | 49.53 | 49.91 | 52.49 | 49.85 | 50.92 | 51.04 | 52.48 | 52.26 | 51.66 | 52.69 | 35.05 | 49.63 |
| $TiO_2$ | 0.31 | 2.70 | 0.18 | 0.30 | 0.23 | 0.37 | 0.24 | 0.23 | 0.20 | 0.41 | 2.24 | 0.65 | 0.43 | 0.43 | 0.47 | 0.83 | 0.51 | 7.86 | 0.26 |
| $Al_2O_3$ | 16.19 | 15.73 | 18.88 | 15.30 | 21.19 | 17.54 | 18.62 | 16.41 | 21.29 | 15.66 | 12.45 | 12.95 | 16.68 | 16.07 | 15.85 | 17.04 | 15.74 | 10.92 | 17.89 |
| $Fe_2O_3$ | 0.54 | 1.78 | 0.30 | 0.61 | 0.27 | 1.35 | 0.41 | 0.85 | 0.65 | 1.51 | 3.64 | 1.63 | 1.27 | 0.97 | 1.73 | 2.84 | 1.33 | 14.43 | 0.76 |
| FeO | 4.32 | 8.07 | 3.79 | 4.11 | 2.82 | 4.71 | 3.37 | 4.05 | 2.92 | 6.17 | 9.14 | 8.66 | 7.88 | 6.32 | 6.26 | 5.53 | 5.98 | 15.78 | 3.55 |
| MnO | 0.11 | 0.17 | 0.08 | 0.11 | 0.07 | 0.12 | 0.08 | 0.10 | 0.07 | 0.16 | 0.24 | 0.22 | 0.17 | 0.16 | 0.16 | 0.16 | 0.17 | 0.32 | 0.09 |
| MgO | 10.38 | 7.22 | 8.54 | 10.69 | 6.24 | 6.60 | 9.99 | 12.60 | 8.41 | 8.55 | 8.01 | 10.14 | 8.89 | 8.18 | 8.23 | 6.93 | 7.91 | 5.43 | 11.04 |
| CaO | 13.15 | 10.91 | 9.84 | 14.10 | 13.66 | 10.44 | 14.32 | 13.33 | 13.00 | 11.20 | 10.62 | 11.28 | 9.48 | 11.54 | 11.29 | 10.38 | 11.76 | 6.81 | 13.88 |
| $Na_2O$ | 2.50 | 3.37 | 3.98 | 2.28 | 3.10 | 4.19 | 2.22 | 2.17 | 2.80 | 3.26 | 2.90 | 2.76 | 3.49 | 3.34 | 3.21 | 3.48 | 3.22 | 2.56 | 2.07 |
| $K_2O$ | 0.09 | 0.06 | 0.08 | 0.05 | 0.05 | 0.05 | 0.02 | 0.04 | 0.04 | 0.03 | 0.05 | 0.07 | 0.04 | 0.03 | 0.03 | 0.05 | 0.03 | 0.06 | 0.03 |
| $P_2O_5$ | 0.01 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.08 | 0.00 |
| $H_2O$ | 0.93 | 0.95 | 1.24 | 0.98 | 0.83 | 0.74 | 0.76 | 0.68 | 0.56 | 0.46 | 0.85 | 0.71 | 0.62 | 0.48 | 0.43 | 0.59 | 0.38 | 0.69 | 0.68 |
| $CO_2$ | nd | 0.10 | 0.12 | 0.13 | nd | nd | nd | 0.01 | 0.14 | 0.11 | nd | nd | nd | nd | 0.10 | 0.50 | 0.30 | nd | 0.11 |
| [4]LOI | 0.87 | 0.84 | 1.49 | 1.01 | 0.86 | 0.56 | 0.78 | 0.64 | 0.74 | 0.18 | 0.28 | 0.42 | +0.15 | 0.23 | 0.18 | 0.92 | 0.09 | +0.71 | 0.76 |
| V | 131 | 388 | 68 | 159 | 87 | 145 | 104 | 107 | 69 | 178 | 509 | 216 | 108 | 174 | 178 | 216 | 193 | 1594 | 144 |
| Cr | 323 | 79 | 147 | 384 | 240 | 12 | 633 | 464 | 320 | 29 | 27 | 43 | 7 | 7 | 15 | 3 | 8 | 79 | 885 |
| Ni | 131 | 132 | 118 | 132 | 64 | 31 | 181 | 239 | 125 | 43 | 39 | 49 | 39 | 33 | 41 | 31 | 35 | 60 | 161 |
| Cu | 34 | 157 | 9.0 | 23 | 9.0 | 15 | 74 | 47 | 35 | 66 | 51 | 36 | 35 | 39 | 67 | 27 | 67 | 199 | 39 |
| Zn | 29 | 36 | 19 | 21 | 15 | 29 | 21 | 25 | 21 | 42 | 80 | 61 | 54 | 40 | 41 | 45 | 43 | 189 | 26 |
| Rb | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | 0.9 | <0.8 | <0.8 | <0.8 | 0.9 | 1.2 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 |
| Sr | 147 | 169 | 182 | 138 | 193 | 202 | 170 | 152 | 198 | 184 | 145 | 153 | 196 | 184 | 175 | 209 | 175 | 128 | 163 |
| Y | 14 | 30 | 24 | 16 | 6 | 16 | 6 | 8 | 5 | 11 | 18 | 16 | 10 | 12 | 11 | 10 | 14 | 14 | 7 |
| Zr | 25.3 | 34.7 | 53.8 | 16.5 | 7.2 | 14.0 | 7.1 | 8.7 | 17.3 | 11.0 | 23.9 | 25.5 | 13.2 | 11.9 | 12.1 | 14.8 | 15.2 | 56 | 8.5 |
| Nb | <0.5 | 2.0 | 1.1 | <0.5 | <0.5 | 0.7 | <0.5 | <0.5 | <0.5 | <0.5 | 1.5 | 0.6 | <0.5 | <0.5 | 0.6 | <0.5 | <0.5 | 4.7 | <0.5 |
| [5]Mg# | 0.82 | 0.61 | 0.81 | 0.83 | 0.81 | 0.70 | 0.85 | 0.84 | 0.83 | 0.70 | 0.57 | 0.68 | 0.67 | 0.70 | 0.69 | 0.64 | 0.70 | 0.29 | 0.84 |
| $MgO/Al_2O_3$ | 0.64 | 0.46 | 0.45 | 0.70 | 0.29 | 0.38 | 0.54 | 0.77 | 0.39 | 0.55 | 0.64 | 0.78 | 0.53 | 0.10 | 0.52 | 0.41 | 0.50 | 0.50 | 0.62 |
| $CaO/Al_2O_3$ | 0.81 | 0.69 | 0.52 | 0.92 | 0.64 | 0.59 | 0.77 | 0.81 | 0.61 | 0.72 | 0.85 | 0.87 | 0.57 | 0.72 | 0.71 | 0.61 | 0.75 | 0.62 | 0.78 |
| $CaO/Na_2O$ | 5.26 | 3.23 | 2.47 | 6.17 | 4.26 | 2.49 | 6.45 | 6.13 | 4.66 | 3.43 | 3.66 | 4.09 | 2.72 | 3.46 | 3.52 | 2.98 | 3.65 | 2.66 | 6.44 |

**Table 4 (continued).**

| Core/section: | 45R-1 | 46R-3 | 46R-4 | 47R-4 | 48R-2 | 50R-2 | 52R-4 | 53R-1 | 53R-5 | 54R-1 | 55R-2 | 58R-3 | 59R-4 | 60R-1 | 61R-1 | 62R-1 | 63R-5 | 65R-3 | 67R-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 48–54 | 121–129 | 109–113 | 80–86 | 109–113 | 43–47 | 88–94 | 47–54 | 40–43 | 131–136 | 101–105 | 107–114 | 29–35 | 80–83 | 81–85 | 91–94 | 126–130 | 54–58 | 74–78 |
| Piece: | 1F | 10 | 11 | 5 | 9 | 1B | 4B | 2C | 3 | 8B | 4 | 1F | 1C | 1E | 3A | 3 | 5A | 1D | 1H |
| Mbsf[1]: | 216.5 | 225.1 | 226.5 | 231.2 | 233.4 | 239.5 | 252.9 | 253.5 | 258.5 | 259.3 | 267.5 | 284.3 | 289.6 | 291.3 | 296.3 | 301.4 | 312.2 | 323.1 | 333.6 |
| Unit[2]: | III | IV | IV | IV | IV | IV | IV | IV | IV | IV | IV | V | V | V | V | V | V | V | V |
| Type[3]: | GO | FGO | FG | OG | FGO | FG | FG | FGO | TJ | FGO | FGO | OG | OG | OG | OG | OG | OG | OG | OG |
| $SiO_2$ | 52.45 | 47.53 | 45.62 | 49.82 | 45.41 | 38.89 | 42.53 | 44.66 | 70.82 | 44.86 | 41.69 | 50.26 | 51.02 | 51.85 | 49.74 | 50.06 | 51.05 | 49.83 | 50.91 |
| $TiO_2$ | 0.90 | 2.58 | 6.10 | 0.29 | 3.73 | 9.08 | 6.89 | 6.34 | 0.22 | 2.33 | 7.23 | 0.37 | 0.49 | 0.36 | 0.34 | 0.35 | 0.28 | 0.33 | 0.32 |
| $Al_2O_3$ | 14.49 | 13.30 | 14.92 | 14.65 | 12.13 | 9.89 | 10.93 | 11.41 | 17.28 | 12.02 | 10.66 | 16.37 | 15.43 | 18.04 | 16.53 | 14.83 | 17.45 | 16.39 | 17.74 |
| $Fe_2O_3$ | 1.61 | 4.02 | 5.55 | 0.27 | 5.51 | 8.32 | 7.34 | 5.15 | 1.24 | 5.35 | 7.33 | 1.39 | 1.28 | 0.41 | 1.04 | 1.28 | 0.53 | 0.67 | 0.96 |
| FeO | 7.55 | 11.02 | 10.27 | 4.46 | 12.76 | 15.29 | 14.06 | 13.51 | 0.00 | 17.69 | 15.13 | 5.46 | 4.84 | 3.57 | 5.62 | 5.82 | 4.41 | 4.78 | 3.05 |
| MnO | 0.20 | 0.23 | 0.20 | 0.11 | 0.25 | 0.28 | 0.30 | 0.28 | 0.02 | 0.42 | 0.30 | 0.13 | 0.13 | 0.10 | 0.13 | 0.14 | 0.10 | 0.11 | 0.09 |
| MgO | 8.03 | 7.48 | 4.27 | 13.24 | 7.36 | 6.30 | 5.50 | 5.48 | 0.17 | 5.03 | 5.29 | 10.32 | 10.08 | 7.61 | 10.66 | 11.33 | 9.53 | 11.41 | 8.95 |
| CaO | 11.11 | 10.08 | 8.74 | 14.66 | 9.37 | 8.85 | 9.21 | 9.52 | 1.93 | 6.72 | 9.15 | 12.51 | 14.03 | 14.72 | 12.93 | 13.62 | 13.10 | 13.72 | 14.84 |
| $Na_2O$ | 3.18 | 3.03 | 3.68 | 1.66 | 2.72 | 2.25 | 2.70 | 3.02 | 6.95 | 3.47 | 2.59 | 2.76 | 2.34 | 2.75 | 2.37 | 2.03 | 2.68 | 2.05 | 2.25 |
| $K_2O$ | 0.05 | 0.05 | 0.05 | 0.00 | 0.04 | 0.04 | 0.04 | 0.04 | 1.48 | 0.17 | 0.05 | 0.04 | 0.02 | 0.03 | 0.01 | 0.01 | 0.03 | 0.02 | 0.01 |
| $P_2O_5$ | 0.02 | 0.00 | 0.01 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 1.20 | 0.03 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| $H_2O$ | 0.41 | 0.69 | 0.60 | 0.81 | 0.58 | 0.81 | 0.52 | 0.61 | nd | 0.75 | 0.55 | 0.39 | 0.25 | 0.59 | 0.65 | 0.53 | 0.84 | 0.71 | 0.78 |
| $CO_2$ | nd | nd | nd | nd | 0.13 | nd | nd | nd | nd | nd | nd | 0.01 | 0.09 | nd | nd | nd | nd | nd | 0.09 |
| [4]LOI | 0.25 | 0.01 | +0.05 | 0.72 | +0.31 | +0.58 | +0.27 | +0.33 | 0.40 | +0.79 | +0.44 | 0.40 | 0.01 | 0.76 | 0.16 | 0.09 | 0.72 | 0.47 | 0.88 |
| V | 243 | 587 | 777 | 149 | 712 | 1173 | 634 | 542 | — | 70 | 628 | 128 | 175 | 139 | 126 | 152 | 120 | 123 | 146 |
| Cr | 10 | 20 | 5 | 822 | 110 | <1 | 6 | 3 | — | <1 | 11 | 212 | 382 | 397 | 305 | 404 | 433 | 584 | 504 |
| Ni | 31 | 30 | 31 | 206 | 39 | 29 | 10 | 8 | — | 10 | 19 | 115 | 108 | 70 | 139 | 125 | 123 | 196 | 114 |
| Cu | 67 | 59 | 71 | 40 | 84 | 106 | 73 | 62 | — | 57 | 86 | 37 | 94 | 50 | 95 | 122 | 20 | 91 | 20 |
| Zn | 54 | 76 | 82 | 24 | 94 | 123 | 120 | 109 | — | 170 | 133 | 38 | 30 | 22 | 35 | 37 | 31 | 30 | 21 |
| Rb | <0.8 | 0.9 | 0.9 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | — | <0.8 | 0.80 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 |
| Sr | 172 | 178 | 200 | 134 | 155 | 125 | 161 | 153 | — | 193 | 155 | 172 | 162 | 180 | 159 | 148 | 165 | 153 | 164 |
| Y | 18 | 15 | 13 | 7 | 16 | 19 | 24 | 23 | — | 69 | 32 | 8 | 11 | 10 | 8 | 10 | 22 | 8 | 8 |
| Zr | 26.9 | 18.0 | 45 | 7.2 | 21 | 52.5 | 48 | 48.6 | — | 59.2 | 104 | 11.0 | 16.4 | 13.5 | 11.6 | 9.8 | 17.5 | 12.7 | 10.8 |
| Nb | 0.8 | 1.6 | 2.8 | 0.8 | 1.8 | 5.0 | 4.1 | 4.0 | — | 5.6 | 6.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.8 | <0.5 | <0.5 |
| [5]Mg# | 0.65 | 0.51 | 0.37 | 0.85 | 0.46 | 0.36 | 0.36 | 0.38 | 0.00 | 0.32 | 0.34 | 0.76 | 0.78 | 0.80 | 0.77 | 0.77 | 0.80 | 0.82 | 0.83 |
| $MgO/Al_2O_3$ | 0.55 | 0.56 | 0.29 | 0.90 | 0.61 | 0.64 | 0.50 | 0.48 | 0.01 | 0.48 | 0.50 | 0.63 | 0.65 | 0.42 | 0.64 | 0.76 | 0.55 | 0.70 | 0.50 |
| $CaO/Al_2O_3$ | 0.77 | 0.76 | 0.59 | 1.00 | 0.77 | 0.89 | 0.84 | 0.83 | 0.11 | 0.56 | 0.86 | 0.76 | 0.91 | 0.82 | 0.78 | 0.92 | 0.75 | 0.84 | 0.84 |
| $CaO/Na_2O$ | 3.49 | 3.33 | 2.35 | 8.81 | 3.44 | 3.92 | 3.41 | 3.16 | 0.28 | 1.94 | 3.54 | 4.53 | 5.98 | 5.34 | 5.46 | 6.70 | 4.89 | 6.70 | 6.60 |

**Table 4 (continued).**

| Core/section: | 68R-2 | 69R-3 | 70R-1 | 70R-2 | 71R-3 | 72R-2 | 73R-1 | 74R-6 | 75R-5 | 76R-3 | 77R-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 16–21 | 86–92 | 80–84 | 129–131 | 0–5 | 56–62 | 54–57 | 115–119 | 27–30 | 93–97 | 4–7 |
| Piece: | 1B | 5C | 3A | 3C | 1A | 1D | 3B | 5B | 1A | 2H | 1A |
| Mbsf[1]: | 336.7 | 344.5 | 346.8 | 353.6 | 353.9 | 358.1 | 366.0 | 383.5 | 390.3 | 397.5 | 405.0 |
| Unit[2]: | V | V | V | V | V | V | V | V | V | V | VI |
| Type[3]: | OG | OG | OG | OG | OG | OG | OG | OG | OG | OG | OG |
| $SiO_2$ | 47.40 | 50.30 | 50.69 | 48.29 | 50.43 | 49.89 | 50.46 | 50.70 | 51.00 | 49.49 | 54.00 |
| $TiO_2$ | 0.23 | 0.34 | 0.32 | 0.28 | 0.32 | 0.38 | 0.34 | 0.27 | 0.29 | 0.25 | 0.49 |
| $Al_2O_3$ | 14.87 | 16.80 | 17.51 | 19.26 | 17.59 | 17.56 | 15.13 | 18.00 | 16.48 | 17.56 | 16.56 |
| $Fe_2O_3$ | 0.59 | 1.23 | 0.32 | 0.73 | 0.94 | 1.05 | 0.83 | 0.69 | 0.43 | 0.94 | 0.92 |
| FeO | 7.29 | 3.80 | 4.10 | 3.44 | 3.80 | 4.45 | 4.14 | 3.27 | 3.74 | 4.53 | 5.95 |
| MnO | 0.14 | 0.10 | 0.10 | 0.12 | 0.10 | 0.11 | 0.11 | 0.09 | 0.10 | 0.10 | 0.16 |
| MgO | 15.98 | 10.52 | 9.68 | 7.92 | 9.96 | 10.45 | 11.53 | 9.37 | 10.10 | 11.41 | 7.02 |
| CaO | 10.97 | 14.17 | 14.29 | 12.58 | 14.03 | 13.43 | 15.14 | 14.64 | 15.33 | 13.04 | 10.19 |
| $Na_2O$ | 1.84 | 2.17 | 2.29 | 3.21 | 2.29 | 2.25 | 1.81 | 2.33 | 2.00 | 2.13 | 3.90 |
| $K_2O$ | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.06 |
| $P_2O_5$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| $H_2O$ | 0.68 | 0.45 | 0.68 | 4.24 | 0.42 | 0.32 | 0.37 | 0.43 | 0.51 | 0.46 | 0.62 |
| $CO_2$ | nd | 0.10 | nd | nd | 0.09 | 0.11 | 0.13 | 0.11 | nd | 0.08 | nd |
| [4]LOI | 0.14 | 0.29 | 0.38 | 0.38 | 0.50 | +0.09 | 0.39 | 0.61 | 0.33 | 0.60 | 1.22 |
| V | 88 | 134 | 133 | 88 | 112 | 116 | 166 | 119 | 139 | 108 | 173 |
| Cr | 353 | 519 | 542 | 317 | 496 | 315 | 544 | 375 | 441 | 335 | 10 |
| Ni | 260 | 149 | 124 | 109 | 134 | 124 | 165 | 114 | 126 | 137 | 24 |
| Cu | 117 | 56 | 41 | 22 | 88 | 60 | 117 | 76 | 100 | 108 | 29 |
| Zn | 45 | 25 | 25 | 37 | 27 | 31 | 26 | 21 | 21 | 29 | 43 |
| Rb | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 |
| Sr | 146 | 161 | 163 | 235 | 164 | 164 | 132 | 167 | 152 | 161 | 203 |
| Y | 6 | 9 | 8 | 17 | 8 | 9 | 9 | 8 | 8 | 6 | 10 |
| Zr | 8.3 | 12.9 | 11.7 | 59 | 11.3 | 15.1 | 11.0 | 9.3 | 8.4 | 7.5 | 13.7 |
| Nb | <0.5 | <0.5 | <0.5 | 1.4 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| [5]Mg# | 0.81 | 0.82 | 0.82 | 0.78 | 0.82 | 0.80 | 0.83 | 0.83 | 0.84 | 0.81 | 0.68 |
| $MgO/Al_2O_3$ | 1.07 | 0.63 | 0.55 | 0.41 | 0.57 | 0.59 | 0.76 | 0.52 | 0.61 | 0.65 | 0.42 |
| $CaO/Al_2O_3$ | 0.74 | 0.84 | 0.82 | 0.65 | 0.80 | 0.76 | 1.00 | 0.81 | 0.93 | 0.74 | 0.62 |
| $CaO/Na_2O$ | 5.96 | 6.54 | 6.23 | 3.92 | 6.12 | 5.96 | 8.37 | 6.30 | 7.67 | 6.12 | 2.60 |

**Table 4 (continued).**

| Core/section: | 78R-1 | 79R-6 | 80R-2 | 80R-6 | 81R-5 | 82R-1 | 83R-7 | 84R-5 | 85R-7 | 87R-7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Interval (cm): | 132–136 | 90–95 | 35–40 | 6–9 | 1–7 | 49–54 | 77–81 | 80–82 | 79–85 | 51–55 |
| Piece: | 5B | 3 | 4 | 1 | 1 | 3 | 4D | 9 | 5 | 6 |
| Mbsf[1]: | 410.8 | 422.7 | 425.8 | 431.4 | 439.2 | 443.5 | 462.0 | 468.5 | 480.7 | 499.7 |
| Unit[2]: | VI | VI | VI | VI | VI | VI | VI | VI | VI | VI |
| Type[3]: | OG | TR | TR | OG | OG | OG | TR | OG | OG | TR |
| $SiO_2$ | 50.00 | 48.33 | 46.28 | 50.66 | 50.81 | 49.36 | 42.35 | 50.86 | 50.23 | 44.87 |
| $TiO_2$ | 0.29 | 0.20 | 0.20 | 0.38 | 0.24 | 0.20 | 0.17 | 0.46 | 0.30 | 0.14 |
| $Al_2O_3$ | 16.84 | 17.62 | 21.52 | 15.04 | 18.17 | 19.04 | 11.99 | 15.09 | 15.85 | 17.42 |
| $Fe_2O_3$ | 0.33 | 1.21 | −0.01 | 0.21 | 0.22 | 0.00 | 1.31 | 0.61 | 0.59 | 1.38 |
| FeO | 4.54 | 4.44 | 4.74 | 5.03 | 4.02 | 4.88 | 6.69 | 4.87 | 3.16 | 5.96 |
| MnO | 0.10 | 0.11 | 0.08 | 0.12 | 0.09 | 0.09 | 0.14 | 0.12 | 0.09 | 0.12 |
| MgO | 11.07 | 13.34 | 12.96 | 11.54 | 9.83 | 13.07 | 24.99 | 10.40 | 10.62 | 17.69 |
| CaO | 14.30 | 12.25 | 11.58 | 14.28 | 13.65 | 12.99 | 8.05 | 14.69 | 16.34 | 8.64 |
| $Na_2O$ | 2.02 | 1.94 | 1.84 | 2.18 | 2.41 | 1.62 | 0.80 | 2.20 | 2.01 | 1.95 |
| $K_2O$ | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.08 | 0.02 |  | 0.02 | 0.06 |
| $P_2O_5$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 |
| $H_2O$ | 0.53 | 0.56 | 0.80 | 0.57 | 0.54 | 0.73 | 3.10 | 0.68 | 0.80 | 1.76 |
| $CO_2$ | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| [4]LOI | 0.45 | 0.32 | 0.42 | 0.35 | 0.37 | 0.85 | 2.37 | 0.53 | 0.68 | 1.44 |
| V | 124 | 69 | 42 | 159 | 92 | 80 | 68 | 184 | 162 | 20 |
| Cr | 753 | 1570 | 222 | 227 | 410 | 402 | 3668 | 318 | 2857 | 52 |
| Ni | 159 | 285 | 392 | 135 | 145 | 234 | 741 | 102 | 190 | 386 |
| Cu | 48 | 51 | 33 | 47 | 90 | 74 | 55 | 83 | 19 | 67 |
| Zn | 27 | 26 | 28 | 28 | 24 | 35 | 53 | 31 | 18 | 43 |
| Rb | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | <0.8 | 0.9 | <0.8 | <0.8 | <0.8 |
| Sr | 145 | 144 | 136 | 129 | 146 | 147 | 80 | 152 | 124 | 143 |
| Y | 7 | 5 | 5 | 10 | 9 | 8 | 4 | 13 | 9 | 2 |
| Zr | 8.8 | 12.7 | 13.2 | 14.0 | 11.8 | 31.9 | 5.3 | 22.7 | 11.4 | 2.7 |
| Nb | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | 0.60 | <0.5 | 0.7 | <0.5 | 0.6 |
| [5]Mg# | 0.83 | 0.83 | 0.85 | 0.82 | 0.83 | 0.85 | 0.87 | 0.80 | 0.86 | 0.84 |
| $MgO/Al_2O_3$ | 0.66 | 0.76 | 0.60 | 0.77 | 0.54 | 0.69 | 2.08 | 0.69 | 0.67 | 1.02 |
| $CaO/Al_2O_3$ | 0.85 | 0.70 | 0.54 | 0.95 | 0.75 | 0.68 | 0.67 | 0.97 | 1.03 | 0.50 |
| $CaO/Na_2O$ | 7.08 | 6.32 | 6.28 | 6.55 | 5.67 | 2.03 | 10.00 | 6.68 | 8.12 | 4.44 |

## Olivine Gabbros

Most of the analyzed samples from Hole 735B are olivine gabbros that are essentially composed of plagioclase (around 60 vol%), clinopyroxene (around 30 vol%), and olivine (5 to 15 vol%). These rocks constitute major portions of lithologic Units II, V, and VI (see "Lithostratigraphy" section, this chapter) and also occur subordinately in Units III and IV. A description of their petrographical and mineralogical characteristics is given in the "Petrography" section (this chapter), which also provides quantitative information on the modal compositions of many of the chemically investigated samples (Table 4).

Table 5 summarizes the average chemical composition of the olivine gabbros within each of the various units and gives the respective range of variation (expressed as ± 1 s in wt%). A close scrutiny of this table reveals that the olivine gabbros from Units II, V, and VI vary within relatively restricted chemical limits and display almost identical average values. This means that according to shipboard data, the olivine gabbros selected from these three major lithologic units exhibit the same overall chemical composition and that no significant chemical differences exist between Units V and VI. Most of the analyzed samples have major oxide compositions in the following ranges (in weight percent):

| | |
|---|---|
| $SiO_2$ | 49.5–51.5 |
| $TiO_2$ | 0.27–0.37 |
| $Al_2O_3$ | 15.5–17.5 |
| $Fe_2O_3$ | 5.0–6.5 |
| MnO | 0.9–12.0 |
| MgO | 0.08–0.22 |
| CaO | 12.5–14.5 |
| $Na_2O$ | 1.7–2.8 |
| $K_2O$ | 0.01–0.05 |

The magnesium numbers are between 0.78 and 0.85, indicating that these rocks crystallized from very primitive basaltic liquids.

Typical concentration ranges (in parts per million) of the trace elements determined are as follows:

| | |
|---|---|
| V | 100–180 |
| Cr | 300–600 |
| Ni | 100–200 |
| Cu | 20–100 |
| Zn | 20–50 |
| Rb | <1 |
| Sr | 120–180 |
| Y | 5–15 |
| Zr | 7–18 |
| Nb | <1 |

Three olivine gabbros analyzed from lithologic Unit III (Samples 118-735B-38R-2, 78–84 cm, Piece 4B; 118-735B-39R-1, 145–147 cm, Piece 3B; and 118-735B-41R-4, 22–27 cm, Piece 1A) form a chemically distinct rock group, which clearly is distinguished from all other olivine gabbros recovered from Hole 735B. Their magnesium numbers of 0.67 to 0.69 indicate crystallization from relatively evolved basaltic liquids. Correspondingly, they show significantly higher contents of $SiO_2$, $TiO_2$, $Fe_2O_3$, MnO, and $Na_2O$ and lower contents of CaO (Table 5). The evolved chemical character of these rocks is also reflected in their low abundances of chromium and nickel, which are in the range of 5–45 ppm and 40–50 ppm, respectively.

**Table 5. Average concentrations (wt%) and variation (±1 s) of the olivine gabbros of the various lithologic units of Hole 735B.**

| Lith. unit: Number of samples: | II<br>13 | IIIA<br>3 | IIIB<br>1 | IV<br>1 | V<br>17 | VI<br>7 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 50.69<br>±1.37 | 51.29<br>±0.76 | 49.83 | 49.98 | 50.31<br>±1.02 | 50.47<br>±1.38 |
| $TiO_2$ | 0.30<br>±0.09 | 0.52<br>±0.12 | 0.26 | 0.29 | 0.34<br>±0.05 | 0.32<br>±0.09 |
| $Al_2O_3$ | 16.46<br>±2.84 | 15.13<br>±1.95 | 17.96 | 14.70 | 16.83<br>±1.42 | 16.58<br>±1.34 |
| $Fe_2O_3$ | 5.42<br>±1.15 | 9.97<br>±1.28 | 4.72 | 5.24 | 5.98<br>±1.31 | 5.40<br>±1.06 |
| MnO | 0.11<br>±0.02 | 0.18<br>±0.03 | 0.09 | 0.11 | 0.11<br>±0.02 | 0.11<br>±0.02 |
| MgO | 11.13<br>±2.65 | 9.07<br>±0.96 | 11.08 | 13.28 | 10.42<br>±1.89 | 10.47<br>±1.56 |
| CaO | 13.48<br>±1.32 | 10.66<br>±1.04 | 13.94 | 14.71 | 13.65<br>±1.06 | 13.48<br>±1.56 |
| $Na_2O$ | 2.39<br>±0.68 | 3.14<br>±0.37 | 2.08 | 1.67 | 2.35<br>±0.40 | 2.28<br>±0.61 |
| Mg # | 0.83<br>±0.02 | 0.68<br>±0.01 | 0.84 | 0.85 | 0.80<br>±0.02 | 0.82<br>±0.05 |

All data anhydrous basis and normalized to sum + 100%; $Fe_2O_3$ = total iron expressed as ferric iron.

### Troctolites

The four troctolite samples selected from the depth interval 422.7 to 500 mbsf (Unit VI) are distinguished by specific chemical features and differ significantly from the olivine gabbros. The high olivine abundance is reflected in high to very high MgO contents, which vary from 13.0 to 25.6 wt%. The magnesium numbers range from 0.83 to 0.87 and are the highest of all rocks analyzed. The average major oxide composition of the troctolites and the variation (± 1 s) is as follows:

| | |
|---|---|
| $SiO_2$ | 45.88 ± 2.08 |
| $TiO_2$ | 0.18 ± 0.03 |
| $Al_2O_3$ | 17.28 ± 3.82 |
| $Fe_2O_3$ | 7.12 ± 1.70 |
| MnO | 0.11 ± 0.03 |
| MgO | 17.46 ± 5.86 |
| CaO | 10.21 ± 2.02 |
| $Na_2O$ | 1.65 ± 0.55 |

These rocks are extremely low in $K_2O$ (<0.02 wt%), rubidium, and niobium (close to or below the detection limits of 0.8 and 0.5 ppm, respectively). The zirconium contents are between 2 and 14 ppm, and yttrium varies from 2 to 5 ppm. The troctolites contain up to 3668 ppm chromium and 747 ppm nickel.

### Iron-Titanium Oxide Gabbros

The iron-titanium enriched and ilmenite- and/or magnetite-bearing gabbros make up large sections of lithologic Unit IV and also occur at specific intervals in Units II, V, and VI. They define a chemically distinct group of plutonic rocks drilled at Hole 735B. In general, they are characterized by unusually high concentrations of iron (up to 30 wt% $Fe_2O_3$) and titanium (up to 9.0 wt% $TiO_2$). The eight analyzed samples selected at different levels (between 225 and 268 mbsf) from Unit IV have the following average major element composition and variation (± 1 s):

| | |
|---|---|
| $SiO_2$ | 43.52 ± 2.76 |
| $TiO_2$ | 5.49 ± 2.38 |
| $Al_2O_3$ | 11.81 ± 1.61 |
| $Fe_2O_3$ | 21.12 ± 3.48 |
| MnO | 0.28 ± 0.06 |
| MgO | 5.79 ± 1.12 |
| CaO | 7.69 ± 2.10 |
| $Na_2O$ | 2.91 ± 0.47 |
| $K_2O$ | 0.06 ± 0.04 |

Except for Sample 118-735B-54R-1, 131-136 cm, Piece 8B, which shows considerable phosphorus enrichment (1.19 wt% $P_2O_5$), the $P_2O_5$ contents are below 0.03 wt%. Because of the very high iron concentrations, the magnesium-numbers of these rocks are the lowest of all samples analyzed and vary between 0.32 and 0.51.

The trace-element chemistry of the iron-titanium oxide gabbros is characterized by significant vanadium enrichment (up to 1173 ppm), low contents of chromium and nickel (mostly $<20$ and $<32$ ppm, respectively), and significant, though somewhat erratic, enhancement of zirconium (up to 105 ppm), yttrium (up to 69 ppm), and niobium (up to 6 ppm) concentrations.

### Trondjhemite

Sample 118-735B-53R-5, 40-43 cm, Piece 3, was recovered from a dikelet (about 4 cm wide) of fine-grained, leucocratic, plagioclase-quartz rock, which according to its macroscopic appearance and mineralogical composition was termed trondjhemite ("plagiogranite"). Our assumption that this felsic vein represents a highly differentiated, late-stage, "granitelike" melt was corroborated by its major oxide composition. The extremely high contents of the alkali elements, sodium and potassium, and of silicon (70.8 wt% $SiO_2$) and the low contents of magnesium, iron, titanium, and calcium define a whole-rock chemistry that corresponds to that of a granitic melt having a very high albite component. Because of the limited amount of rock material available, this sample was not analyzed for trace elements.

### Basalt Dike

A basaltic dike having well-developed chilled margins against the gabbro cuts the plutonic sequence in Core 118-735B-23R (see "Petrography" section, this chapter). Sample 118-735B-23R-4, 83-86 cm, Piece 5, was selected from the aphyric part of this aphyric to sparsely olivine-phyric dike rock. Chemically, this basalt closely resembles the basalts recovered at Site 732 (see "Geochemistry" section, Site 732 chapter, this volume), and according to its high zirconium/niobium (38) and yttrium/niobium (10) ratios can be assigned to the group of depleted normal-type mid-ocean ridge basalts.

Among the gabbroic rocks analyzed are four additional samples that definitely lie outside the chemical spectrum defined by the various types of gabbros and that, according to their higher zirconium, yttrium, and niobium contents, may represent liquid rather than cumulate compositions. The samples belong to the deformed series of lithologic Unit I (Sample 118-735B-6D-1, 71-74 cm, Piece 13, a mylonitic gabbro) and to a deformed interval of Unit II (Samples 118-735B-15R-1, 90-93 cm, Piece 7B, a porphyroclastic metagabbro; and 118-735B-16R-1, 139-141 cm, Piece 3H, described as a gneissic metagabbro). A fourth zirconium- and yttrium-enriched sample (118-735B-17R-1, 22-27 cm, Piece 5) is an undeformed olivine-bearing gabbro. Trace-element ratios in these rocks are similar to those of depleted normal mid-ocean ridge basalts. These observations suggest that the four zirconium- and yttrium-enriched samples are either gabbros containing an unusually high amount of trapped basaltic liquid, or deformed and recrystallized basaltic dikes.

### Chemical Stratigraphy

Figure 46 presents the downhole distribution of the major oxides (in weight percent) $SiO_2$, $Al_2O_3$, CaO, $Na_2O$, MgO, total iron as $Fe_2O_3$, $TiO_2$, and the trace elements, nickel and chromium (in parts per million). In addition, plotted as a function of depth (mbsf) are the magnesium-numbers of the samples (calculated as the molar ratio, $Mg/(Mg + 0.86\ Fe_{tot})$ and their $MgO/Al_2O_3$ ratios, which provide some information about the degree of chemical evolution of the rocks. Figure 47 shows the downhole variation of the $MgO/Al_2O_3$ ratio, a measure of the proportion of mafic minerals to plagioclase, of Fe-Ox (ratio of actual $Fe_2O_3$ content to total iron, expressed as $Fe_2O_3$), a measure of the degree of iron oxidation, of wt% $H_2O$, and of concentrations (in parts per million) of the trace elements, copper, zinc, strontium, yttrium, and zirconium.

A preliminary evaluation of these figures shows that despite a certain scatter of the data, significant downhole variations in rock composition exist and that several zones having distinct chemical features can be recognized. Outstanding is the depth interval at about 250 mbsf, which is characterized by locally extreme iron and titanium enrichments. Rocks of this zone show the lowest overall concentrations in $SiO_2$, $Al_2O_3$, CaO, and MgO and have the lowest magnesium-numbers; i.e., they represent the most evolved lithologies. In keeping with this are the very low abundances of nickel and chromium. The lower boundary of this zone is defined by a pronounced chemical discontinuity between Cores 118-735B-56R and 118-735B-58R, i.e., at a depth of about 280 mbsf. This boundary coincides with the boundary of lithologic Units IV and V. The upper boundary of this iron-titanium-rich chemical zone is marked by a change in the downhole gradients of $SiO_2$, MgO, $Fe_2O_3$, $TiO_2$, and the magnesium-numbers. This boundary can be placed at a depth of about 220 mbsf (i.e., between Sections 118-735B-45R-1 and 118-735B-46R-3). There is excellent agreement with the lithostratigraphic subdivision, which places the boundary between Units III and IV at 224 mbsf.

Farther up, the next obvious chemical change occurs at about 180 mbsf (between Sections 118-735B-36R-2 and 118-735B-36R-4) and is well defined by a discontinuity in the nickel and chromium contents, as well as in the magnesium-numbers. This boundary closely matches the transition between lithologic Units II and III.

Sample density and possible small-scale variations in lithology do not yet allow us to draw reliable chemical boundaries in the higher parts of the recovered gabbro section. However, the data available suggest that there is a chemical change at a depth of about 40 mbsf, which coincides with the boundary of the uppermost deformed gabbro suite and the underlying massive gabbro sequence.

A further chemical boundary corresponding to the transition of lithologic Units V and VI can be found at 400 mbsf (between Cores 118-735B-76R and 118-735B-77R).

#### *Trace-Element Variations*

The strongly compatible trace elements nickel and chromium show clear-cut differences in concentration among the various lithologic units (Fig. 47). Abundances of nickel and chromium in Units I, III, and IV are low, which agrees with the lower magnesium-numbers. In particular, the transition between Units II and III is marked by a sharp decrease in concentrations of nickel and chromium. The scattered nickel and chromium contents in lithologic Unit II are somewhat larger than in Units V and VI (aside from the troctolites) and mirror the larger scatter of the magnesium-numbers in Unit II.

Vanadium (when above the detection limit of 0.5 ppm) correlates with $TiO_2$ and shows a pronounced enrichment in the iron-titanium oxide gabbros. Unit IV is also enriched in zinc and to lesser extent, so is Unit I. Copper contents vary erratically. Because the precision of XRF determinations of copper and zinc is similar, the larger scatter of copper suggests control by minor sulfide phases.

The abundances of strontium appear to be determined largely by the proportions of strontium-rich plagioclase. Hence, strontium contents inversely correlate with $MgO/Al_2O_3$ ratios (Fig. 48).

In most samples, rubidium contents are below the detection limit of 0.8 ppm. Values above the detection limit are generally

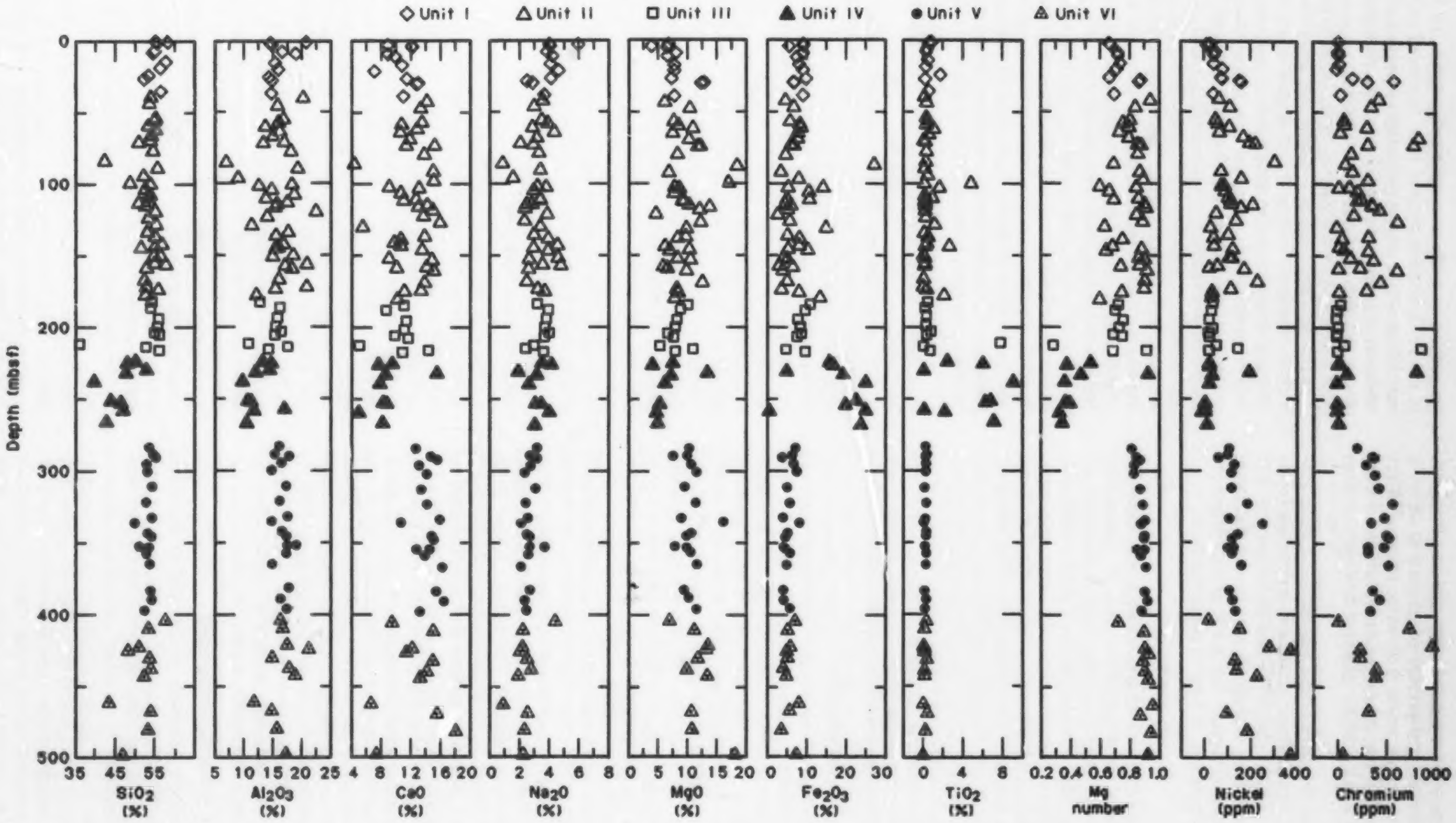

Figure 46. Downhole variation in chemical composition of Hole 735B samples. The six different symbols represent the six different lithologic units.

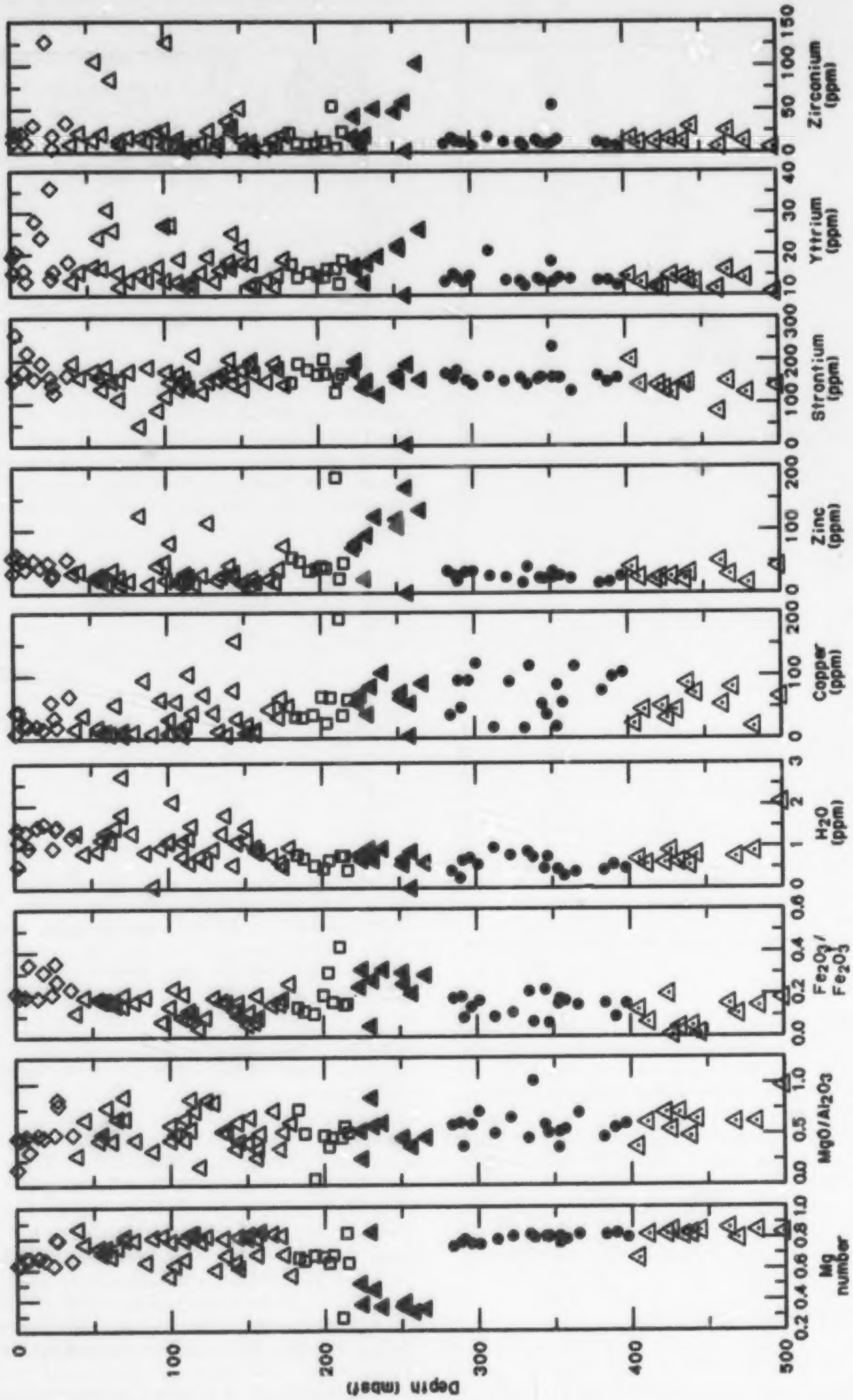

Figure 47. Downhole variation in chemical composition of Hole 735B samples. Symbols as in Figure 46.

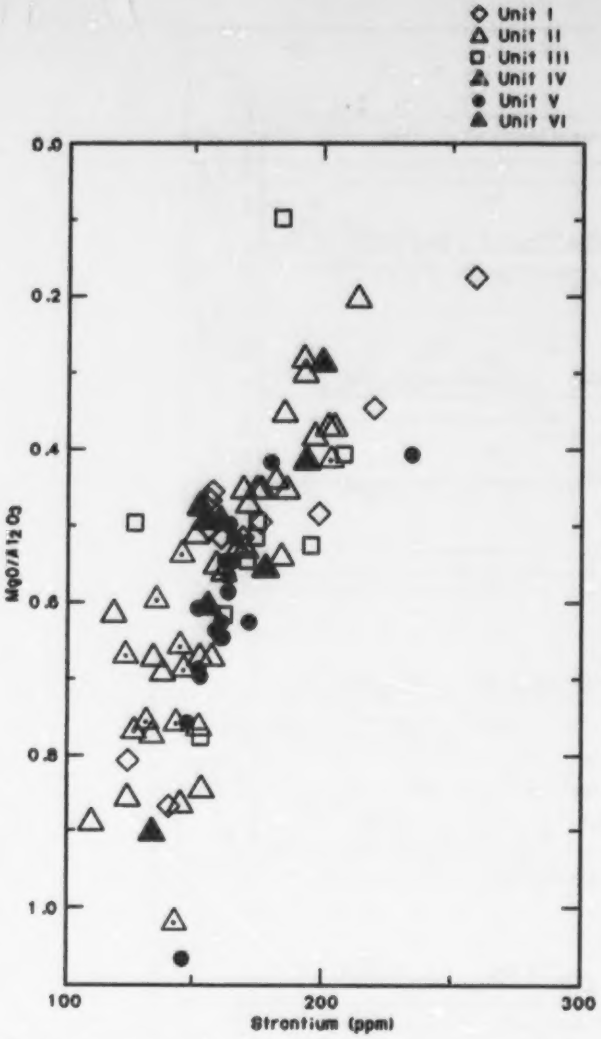

Figure 48. Strontium vs. $MgO/Al_2O_3$ ratio of Hole 735B samples. Symbols as in Figure 46.

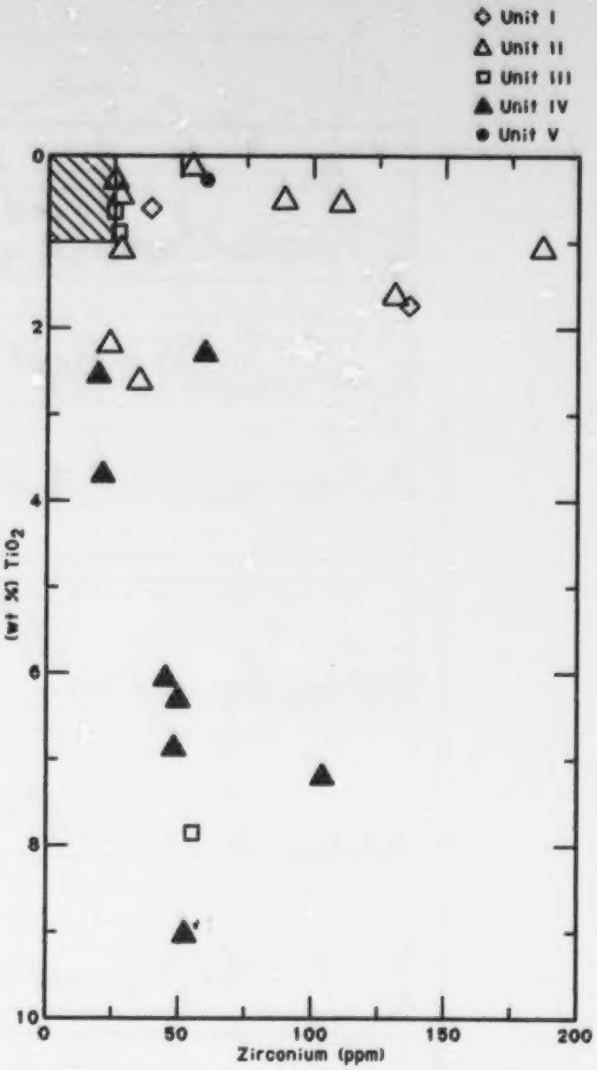

Figure 49. Zirconium vs. $TiO_2$ of Hole 735B samples. Symbols as in Figure 46. Most samples lie within hatched box area.

accompanied by higher potassium contents. The higher values in Unit I most likely reflect uptake from seawater during low-temperature alteration. Zirconium and yttrium show limited variation in the various gabbro types. There is slight zirconium enrichment in the iron-titanium oxide gabbros (Fig. 49). Samples having high zirconium values (>80 ppm) include the basalt dike and the four anomalous gabbros mentioned previously. The samples that are part of the high zirconium/titanium trend also show significant enrichment of yttrium. Otherwise, yttrium abundances appear to be determined largely by the proportion of clinopyroxene and, as opposed to strontium, are positively correlated with $MgO/Al_2O_3$ ratios.

## PALEOMAGNETICS

### Introduction

The Vine-Matthews (1963) model of linear marine magnetic anomalies is central to our understanding of plate tectonics and has been widely applied in the study of marine geological and geophysical processes. Identification of the source layer for these anomalies has been attempted using inversion of marine magnetic anomaly field data and direct measurements of samples acquired by dredging, by DSDP drilling, and by sampling ophiolites. Although some of these studies suggest that the upper extrusive layer can account for the magnetic anomaly observed at the sea surface (Atwater and Mudie, 1973; Klitgord et al., 1975; Macdonald, 1977; Johnson, 1979; Swift and Johnson, 1984), other studies indicate that the magnetic structure of oceanic crust is very complex and that a contribution from the lower, intrusive layers is required (Fox and Opdyke, 1973; Kent et al., 1978; Harrison, 1981; Banerjee, 1984). To date, however, sampling of *in-situ* lower oceanic crust has been restricted to the sheeted dike complex sampled at DSDP Hole 504B (Smith and Banerjee, 1986) and to unoriented dredge samples (Kent et al., 1978).

Hole 735B penetrated 500.7 m into gabbro, with nearly 87% recovery, thus providing the first continuous, vertically oriented suite of plutonic rocks from the oceanic crust. A shipboard paleomagnetic study was conducted on recovered samples (1) to examine their contribution to an overlying marine magnetic anomaly, (2) to characterize their magnetic properties as a function of lithology and alteration, and (3) to provide a "ground truth" for downhole magnetic logging data acquired in this hole.

### Experimental Methods

Minicores 2.5 cm in diameter and about 2.5 cm long were drilled from vertically oriented sections of the recovered drill core. A total of 135 samples was taken for an average sample interval of 4 m. Paleomagnetic measurements were performed using a spinner magnetometer, and stepwise alternating-field demagnetization (AFD) was conducted with a single-axis demagnetizer (see "Introduction and Explanatory Notes" chapter, this volume). Most samples were demagnetized until less than 15% of the natural remanent magnetization (NRM) remained. Two samples were not demagnetized because their original remanence was near the noise level of the spinner (Samples 118-735B-23R-4, 26–28 cm, Piece 1B, and 118-735B-38R-2, 15–17 cm, Piece 1B). Four samples were progressively thermally demagnetized (Samples 118-735B-3D-1, 60–62 cm, Piece 11; 118-735B-19R-3, 73–75 cm, Piece 6A; 118-735B-38R, 28–30 cm, Piece 1C; and 118-735B-54R-5, 117–119 cm, Piece 5; see "Introduction and Explanatory Notes" chapter, this volume). Magnetic susceptibility was measured with an induction-type sensor, and Koenigsberger ratios were calculated assuming a value of 0.38 Oe for Site 735 (Merrill and McElhinny, 1983). The above described parameters are displayed in Table 6.

Zijderveld diagrams were plotted from demagnetization data, and stable inclinations and declinations were determined using a least-squares approximation. Although ODP hard-rock cores are only oriented vertically, further shore-based studies will attempt azimuthal orientation using *in-situ* magnetic data acquired with a gyroscopically oriented magnetometer (see "Magnetometer Logs" section, this chapter). Table 7 contains natural remanent inclinations, stable inclinations, and uncorrected stable declinations.

### Results

#### *Intensity of Remanent Magnetization ($J_0$)*

$J_0$ values are displayed in Figure 50. The most salient feature of this plot is the extremely large range of observed $J_0$ values. In comparison, gabbros dredged from the Kane Fracture Zone have an average value that falls within this range ($820 \times 10^{-6}$ emu/cm$^3$, Fox and Opdyke, 1973). Many of the gabbros from Site 735 are of a similar order of magnitude but have dramatically higher values. In fact, two of the measured samples (Samples 118-735B-32R-1, 64–66 cm, Piece 1F, and 118-735B-44R-2, 6–8 cm, Piece 1A) over-ranged the magnetometer and thus must have values greater than 2.5 emu/cm$^3$. The high $J_0$ values are most commonly from gabbros containing extremely large amounts of iron-titanium oxide minerals (see "Oxide and Sulfide Mineralogy" section, this chapter). Such gabbros were recovered throughout much of the drilled section and are the dominant lithology from 224 to 272 mbsf. Further shore-based studies will be conducted in an effort to correlate the variation in magnetization with deformation, alteration, and lithology.

#### *Magnetic Susceptibility ($X_0$)*

$X_0$ values are plotted in Figure 51. Although a large range of values can be seen, there is much less scatter than is observed in $J_0$, and most samples have values less than $1000 \times 10^{-6}$ cgs. The values from Hole 735B fall within the range of values observed from dredged gabbros by both Fox and Opdyke (1973) and Kent et al. (1978). The highest $X_0$ values from Hole 735B were observed in the magnetite-ilmenite-rich gabbros. Many of

**Table 6. Results of paleomagnetic measurements of samples from Hole 735B.**

| Core/section (cm) | Depth (mbsf) | $J_0$ | $X_0$ | MDF | $Q$ |
|---|---|---|---|---|---|
| 118-735B-1D-1, 19 | 0.19 | 381 | 526 | 235 | 1.9 |
| 1D-1, 141 | 1.41 | 379 | 248 | 230 | 4.0 |
| 2D-1, 113 | 7.63 | 438 | 300 | 70 | 3.8 |
| 2D-1, 139 | 7.89 | 418 | 408 | 178 | 2.7 |
| 2D-2, 99 | 8.99 | 334 | 250 | 140 | 3.5 |
| 3D-1, 60 | 15.10 | 586 | 199 | −100 | 7.8 |
| 4D-2, 7 | 19.07 | 2,443 | 1455 | 100 | 4.4 |
| 6D-1, 111 | 25.11 | 205 | 136 | 170 | 4.0 |
| 7D-1, 74 | 26.74 | 637 | 374 | 150 | 4.5 |
| 7D-2, 9 | 27.39 | 671 | 499 | 75 | 3.5 |
| 8D-1, 45 | 29.65 | 562 | 112 | 235 | 13.2 |
| 9D-1, 120 | 34.40 | 311 | 322 | 130 | 2.5 |
| 10D-1, 24 | 36.44 | 231 | 227 | 330 | 2.7 |
| 11D-1, 6 | 39.26 | 98,970 | −100 | −100 | −100.0 |
| 12R-1, 32 | 39.72 | 4,767 | 3410 | 90 | 3.7 |
| 12R-2, 36 | 41.26 | 624 | 1710 | 155 | 1.0 |
| 12R-3, 8 | 42.48 | 295 | 993 | 63 | 0.8 |
| 12R-3, 83 | 43.23 | 1,327 | 194 | 330 | 18.0 |
| 13R-1, 102 | 45.02 | 1,223 | 640 | 230 | 5.0 |
| 13R-2, 55 | 46.55 | 97 | 278 | 475 | 0.9 |
| 14R-1, 35 | 51.55 | 2,148 | 1900 | 97 | 3.0 |
| 14R-2, 22 | 52.92 | 544 | 377 | 185 | 3.8 |
| 14R-4, 22 | 55.92 | 2,579 | 896 | 105 | 7.6 |
| 15R-2, 128 | 58.98 | 4,119 | 1680 | 30 | 6.5 |
| 16R-1, 139 | 63.19 | 91 | 79 | 410 | 3.0 |
| 16R-4, 77 | 67.07 | 270 | 53 | 420 | 13.4 |
| 16R-5, 24 | 67.30 | 937 | 324 | 25 | 7.6 |
| 18R-3, 29 | 71.79 | 23 | 43 | 255 | 1.4 |
| 19R-3, 73 | 78.43 | 1,202 | 595 | −100 | 5.3 |
| 19R-5, 126 | 81.54 | 323 | 673 | 20 | 1.3 |
| 20R-2, 54 | 86.24 | 1,550 | 550 | 350 | 7.4 |
| 21R-2, 49 | 91.19 | 1,481 | 541 | 240 | 7.2 |
| 22R-2, 41 | 95.91 | 139 | 620 | 410 | 0.6 |
| 22R-3, 118 | 98.18 | 1,369 | 614 | 60 | 5.9 |
| 23R-2, 34 | 102.34 | 686 | 310 | 185 | 5.8 |
| 23R-4, 120 | 106.20 | 5 | 56 | −100 | 0.2 |
| 24R-2, 95 | 107.95 | 37,586 | −100 | 38 | −100.0 |
| 24R-3, 50 | 109.00 | 10,944 | −100 | 225 | −100.0 |
| 24R-4, 26 | 110.23 | 6,801 | 383 | 40 | 46.7 |
| 25R-2, 5 | 112.05 | 180 | 62 | 260 | 7.7 |
| 25R-3, 137 | 114.87 | 678 | 481 | 185 | 3.7 |
| 26R-1, 62 | 116.22 | 2,997 | 2035 | 60 | 3.9 |
| 27R-1, 84 | 122.34 | 1,270 | 564 | 200 | 5.9 |
| 27R-3, 32 | 124.82 | 602 | 434 | 150 | 3.6 |
| 28R-2, 12 | 127.96 | 7,242 | 2515 | 60 | 7.6 |
| 28R-2, 114 | 128.98 | 929 | 298 | 215 | 8.2 |
| 29R-2, 46 | 133.46 | 576 | 384 | 600 | 3.9 |
| 29R-4, 19 | 135.85 | 181 | 90 | 450 | 5.3 |
| 30R-3, 137 | 140.87 | 28,023 | −100 | 25 | −100.0 |
| 30R-4, 14 | 141.14 | 1,958 | 1144 | 15 | 4.5 |
| 30R-5, 91 | 143.21 | 2,370 | 2065 | 45 | 3.0 |
| 31R-2, 120 | 146.20 | 1,130 | 644 | 20 | 4.6 |
| 31R-4, 118 | 148.98 | 1,737 | 608 | 15 | 7.5 |
| 32R-1, 64 | 149.14 | 2,500,000 | −100 | −100 | −100.0 |
| 32R-3, 14 | 151.64 | 973 | 161 | 370 | 15.9 |
| 33R-4, 27 | 158.27 | 3,254 | 5725 | 20 | 1.5 |
| 33R-4, 129 | 159.29 | 552 | 630 | 30 | 2.3 |
| 34R-1, 103 | 159.53 | 565 | 240 | 675 | 6.2 |
| 34R-4, 30 | 162.76 | 44 | 305 | −100 | 0.4 |
| 35R-1, 29 | 163.79 | 601 | 224 | 500 | 7.1 |
| 35R-5, 131 | 170.81 | 245 | 194 | 20 | 3.3 |
| 36R-2, 11 | 172.61 | 922 | 1102 | 300 | 2.2 |
| 36R-3, 36 | 174.36 | 2,552 | 1148 | 200 | 5.8 |
| 37R-1, 11 | 176.11 | 1,034 | 1061 | 320 | 2.6 |
| 37R-3, 80 | 179.80 | 5,541 | 4469 | 20 | 3.3 |
| 38R-2, 15 | 182.65 | 3 | 48 | −100 | −100.0 |
| 38R-4, 28 | 185.78 | 1,525 | 1800 | −100 | −100.0 |
| 39R-1, 145 | 187.45 | 1,206 | 1169 | 310 | 2.7 |
| 39R-3, 21 | 189.21 | 2,213 | 389 | 380 | 15.0 |
| 40R-2, 62 | 193.12 | 1,144 | 290 | 210 | 10.4 |
| 40R-5, 13 | 196.05 | 1,040 | 749 | 600 | 3.7 |
| 41R-4, 68 | 200.86 | 1,078 | 1070 | 440 | 2.7 |
| 42R-2, 119 | 203.69 | 2,573 | 1405 | 20 | 4.8 |
| 42R-4, 62 | 206.12 | 2,683 | 1248 | 240 | 5.7 |
| 43R-1, 126 | 207.26 | 1,204 | 1003 | 265 | 3.2 |
| 43R-4, 64 | 211.14 | 7,424 | 3152 | 25 | 6.2 |
| 44R-2, 6 | 212.56 | 2,500,000 | −100 | −100 | −100.0 |

Table 6 (continued).

| Core/section (cm) | Depth (mbsf) | $J_o$ | $X_o$ | MDF | $Q$ |
|---|---|---|---|---|---|
| 118-735B-44R-2, 131 | 213.81 | 4,236 | 1868 | 20 | 6.0 |
| (Cont.) 45R-2, 15 | 217.65 | 118 | 105 | 30 | 3.0 |
| 46R-2, 21 | 222.71 | 645 | 773 | 680 | 2.2 |
| 46R-2, 128 | 223.78 | 599 | 400 | 35 | 3.9 |
| 47R-3, 50 | 229.50 | 3,808 | 1852 | 35 | 5.4 |
| 48R-4, 82 | 236.32 | 34,618 | −100 | 40 | −100.0 |
| 49R-2, 89 | 238.39 | 13,117 | −100 | 30 | −100.0 |
| 50R-4, 87 | 243.37 | 8,881 | 4996 | 35 | 4.7 |
| 51R-1, 102 | 244.02 | 24,618 | −100 | 30 | −100.0 |
| 52R-4, 69 | 253.19 | 35,704 | −100 | 40 | −100.0 |
| 53R-3, 15 | 256.15 | 30,586 | −100 | 40 | −100.0 |
| 54R-3, 125 | 262.25 | 33,961 | −100 | 40 | −100.0 |
| 54R-5, 117 | 265.17 | 21,004 | −100 | −100 | −100.0 |
| 55R-3, 130 | 269.30 | 56,689 | −100 | 40 | −100.0 |
| 56R-2, 11 | 271.61 | 8,951 | 4213 | 40 | 5.6 |
| 56R-2, 144 | 272.94 | 41 | 177 | 600 | 0.6 |
| 57R-2, 135 | 277.85 | 1,150 | 1085 | 700 | 2.8 |
| 58R-2, 33 | 282.33 | 2,751 | 852 | 340 | 8.5 |
| 59R-3, 70 | 289.20 | 2,230 | 475 | 900 | 12.4 |
| 60R-1, 18 | 290.68 | 1,860 | 389 | 900 | 12.6 |
| 61R-1, 81 | 296.31 | 993 | 645 | 550 | 4.0 |
| 62R-3, 104 | 304.54 | 5,269 | 871 | 410 | 15.9 |
| 63R-3, 80 | 309.30 | 1,550 | 510 | 360 | 8.0 |
| 63R-6, 28 | 313.28 | 517 | 794 | 575 | 1.7 |
| 64R-2, 54 | 317.04 | 910 | 1089 | 380 | 2.2 |
| 65R-2, 67 | 322.17 | 3,137 | 487 | 310 | 17.0 |
| 66R-2, 86 | 327.36 | 6,777 | 364 | 260 | 49.0 |
| 66R-3, 134 | 329.34 | 253 | 34 | −100 | 19.6 |
| 68R-3, 15 | 338.15 | 831 | 716 | 20 | 3.1 |
| 69R-4, 138 | 346.88 | 556 | 304 | 460 | 4.8 |
| 70R-1, 105 | 347.05 | 215 | 67 | 280 | 8.5 |
| 71R-2, 82 | 353.32 | 148 | 440 | 800 | 0.9 |
| 72R-3, 36 | 359.36 | 174 | 77 | 900 | 5.9 |
| 72R-6, 106 | 364.56 | 298 | 265 | 650 | 3.0 |
| 73R-3, 73 | 369.23 | 191 | 70 | 460 | 7.2 |
| 74R-2, 38 | 376.88 | 537 | 150 | 800 | 9.4 |
| 74R-6, 41 | 382.91 | 9,013 | 5606 | 50 | 4.2 |
| 75R-3, 48 | 387.98 | 260 | 246 | 270 | 2.8 |
| 75R-6, 75 | 392.75 | 126 | 120 | 30 | 2.8 |
| 76R-3, 50 | 397.50 | 9,139 | 3649 | 30 | 6.6 |
| 77R-4, 70 | 408.70 | 3,540 | 2092 | 30 | 4.5 |
| 78R-4, 65 | 414.65 | 293 | 126 | 30 | 6.1 |
| 79R-2, 65 | 416.65 | 8,037 | 4520 | 25 | 4.8 |
| 79R-7, 99 | 424.49 | 103 | 131 | 25 | 2.1 |
| 80R-1, 131 | 425.31 | 1,090 | 965 | 40 | 3.0 |
| 80R-7, 23 | 433.23 | 7,493 | 4093 | 40 | 4.9 |
| 81R-2, 54 | 435.54 | 230 | 223 | 20 | 2.7 |
| 81R-7, 64 | 442.84 | 145 | 126 | 165 | 3.0 |
| 82R-2, 13 | 444.63 | 223 | 176 | 30 | 3.3 |
| 82R-6, 11 | 450.61 | 34,064 | −100 | 40 | −100.0 |
| 83R-4, 95 | 457.95 | 248 | 178 | 30 | 3.7 |
| 83R-7, 104 | 462.54 | 289 | 330 | 35 | 2.3 |
| 84R-2, 67 | 464.17 | 1,329 | 508 | 20 | 6.9 |
| 84R-3, 14 | 465.14 | 596 | 885 | 350 | 1.8 |
| 85R-4, 9 | 476.09 | 1,475 | 1016 | 20 | 3.8 |
| 85R-7, 17 | 480.67 | 1,108 | 535 | 20 | 5.5 |
| 86R-6, 143 | 489.93 | 12,205 | −100 | 40 | −100.0 |
| 87R-5, 20 | 496.70 | 16,529 | −100 | 60 | −100.0 |

Depth is in meters below seafloor, $J_o$ is the intensity of natural remanent magnetization in $10^{-6}$ emu/cm$^3$, $X_o$ is magnetic susceptibility in $10^{-6}$ cgs units, MDF is the median demagnetizing field in Oersteds, and $Q$ is the Koenigsberger ratio. Values of − 100 indicate a parameter that could not be obtained for a particular sample. Note that the two samples that over-ranged the magnetometer were given values of 2,500,000 × $10^{-6}$ emu/cm$^3$, which is the maximum value that the magnetometer can measure.

these samples over-ranged the susceptibility meter and thus must have values greater than 10,000 × $10^{-6}$ cgs. Because susceptibility is directly related to grain size and concentration of magnetic minerals and because the magnetite gabbros were observed to have both high contents of magnetite and large grain sizes, the high susceptibility values are not surprising.

Table 7. Magnetic directions of samples from Hole 735B.

| Core/section (cm) | Depth (mbsf) | $I_{nrm}$ | $I_s$ | Dec |
|---|---|---|---|---|
| 118-735B-1D-1, 19 | 0.19 | 68.7 | 72 | 333 |
| 1D-1, 141 | 1.41 | 71.8 | 70 | 135 |
| 2D-1, 113 | 7.63 | 62.1 | 57 | 137 |
| 2D-1, 139 | 7.89 | 78.4 | 69 | 320 |
| 2D-2, 99 | 8.99 | 69.0 | 73 | 315 |
| 3D-1, 60 | 15.10 | 76.1 | 74 | 61 |
| 4D-2, 7 | 19.07 | 57.2 | 51 | 250 |
| 6D-1, 111 | 25.11 | 67.7 | 68 | 190 |
| 7D-1, 74 | 26.74 | 74.9 | 74 | 0 |
| 7D-2, 9 | 27.39 | 86.0 | 87 | 330 |
| 8D-1, 45 | 29.65 | 75.0 | 75 | 250 |
| 9D-1, 120 | 34.40 | 78.5 | 76 | 159 |
| 10D-1, 24 | 36.44 | 86.4 | 84 | 231 |
| 11D-1, 6 | 39.26 | 76.4 | −100 | −100 |
| 12R-1, 32 | 39.72 | 53.6 | 54 | 53 |
| 12R-2, 36 | 41.26 | 36.8 | 80 | 208 |
| 12R-3, 8 | 42.48 | 13.7 | 68 | 61 |
| 12R-3, 83 | 43.23 | 18.3 | 18 | 126 |
| 13R-1, 102 | 45.02 | 66.5 | 67 | 52 |
| 13R-2, 55 | 46.55 | 78.5 | 75 | 153 |
| 14R-1, 35 | 51.55 | 66.0 | 69 | 126 |
| 14R-2, 22 | 52.92 | 83.6 | 78 | 199 |
| 14R-4, 22 | 55.92 | 69.1 | 69 | 24 |
| 15R-2, 128 | 58.98 | −70.3 | 45 | 261 |
| 16R-1, 139 | 63.19 | −19.0 | 31 | 152 |
| 16R-4, 77 | 67.07 | 86.8 | 83 | 194 |
| 16R-5, 24 | 67.30 | −74.5 | 63 | 61 |
| 18R-3, 29 | 71.79 | 81.3 | 79 | 247 |
| 19R-3, 73 | 78.43 | 89.6 | 81 | 215 |
| 19R-5, 126 | 81.54 | −58.5 | 79 | 139 |
| 20R-2, 54 | 86.24 | 73.3 | 52 | 48 |
| 21R-2, 49 | 91.19 | 60.1 | 71 | 339 |
| 22R-2, 41 | 95.91 | 69.1 | 64 | 70 |
| 22R-3, 118 | 98.18 | 80.1 | 75 | 214 |
| 23R-2, 34 | 102.34 | 73.7 | 64 | 175 |
| 23R-4, 120 | 106.20 | 53.5 | −100 | −100 |
| 24R-2, 95 | 107.95 | 58.4 | 51 | 295 |
| 24R-3, 50 | 109.00 | 75.8 | 78 | 325 |
| 24R-4, 26 | 110.23 | 80.1 | 75 | 112 |
| 25R-2, 5 | 112.05 | 62.6 | 70 | 19 |
| 25R-3, 137 | 114.87 | 73.3 | 73 | 147 |
| 26R-1, 62 | 116.22 | 79.2 | 73 | 248 |
| 27R-1, 84 | 122.34 | 29.5 | 31 | 316 |
| 27R-3, 32 | 124.82 | 74.7 | 80 | 358 |
| 28R-2, 12 | 127.96 | 68.0 | 72 | 42 |
| 28R-2, 114 | 128.98 | 84.1 | 77 | 72 |
| 29R-2, 46 | 133.46 | 51.8 | 83 | 53 |
| 29R-4, 19 | 135.85 | 59.6 | 65 | 212 |
| 30R-3, 137 | 140.87 | −55.4 | 44 | 316 |
| 30R-4, 14 | 141.14 | −64.4 | 69 | 44 |
| 30R-5, 91 | 143.21 | −72.2 | 67 | 181 |
| 31R-2, 120 | 146.20 | −74.8 | 44 | 232 |
| 31R-4, 118 | 148.98 | −75.8 | 68 | 196 |
| 32R-1, 64 | 149.14 | −70.8 | −100 | −100 |
| 32R-3, 14 | 151.64 | 66.0 | 67 | 66 |
| 33R-4, 27 | 158.27 | −77.7 | 67 | 20 |
| 33R-4, 129 | 159.29 | −69.4 | 75 | 135 |
| 34R-1, 103 | 159.53 | 5.4 | 78 | 48 |
| 34R-4, 30 | 162.76 | −74.8 | −100 | −100 |
| 35R-1, 29 | 163.79 | 71.2 | 69 | 195 |
| 35R-5, 131 | 170.81 | −70.7 | 68 | 159 |
| 36R-2, 11 | 172.61 | −73.6 | 79 | 189 |
| 36R-3, 36 | 174.36 | 74.5 | 83 | 94 |
| 37R-1, 11 | 176.11 | −30.7 | 80 | 140 |
| 37R-3, 80 | 179.80 | −67.4 | 75 | 152 |
| 38R-2, 15 | 182.65 | −60.7 | −100 | −100 |
| 38R-4, 28 | 185.78 | 47.9 | −64 | 238 |
| 39R-1, 145 | 187.45 | −49.0 | 68 | 120 |
| 39R-3, 21 | 189.21 | 66.8 | 75 | 130 |
| 40R-2, 62 | 193.12 | 83.5 | 80 | 163 |
| 40R-5, 13 | 196.05 | 15.8 | 68 | 107 |
| 41R-4, 68 | 200.86 | 64.5 | 62 | 210 |
| 42R-2, 119 | 203.69 | −49.7 | 76 | 24 |
| 42R-4, 62 | 206.12 | −40.0 | 70 | 353 |
| 43R-1, 126 | 207.26 | 32.4 | 69 | 125 |
| 43R-4, 64 | 211.14 | −75.0 | 62 | 141 |

**Table 7 (continued).**

| Core/section (cm) | | Depth (mbsf) | $I_{nrm}$ | $I_s$ | Dec |
|---|---|---|---|---|---|
| 118-735B- | 44R-2, 6 | 212.56 | −81.1 | −100 | −100 |
| (Cont.) | 44R-2, 131 | 213.81 | −77.7 | 59 | 194 |
| | 45R-2, 15 | 217.65 | −66.1 | 31 | 262 |
| | 46R-2, 21 | 222.71 | −2.2 | 59 | 108 |
| | 46R-2, 128 | 223.78 | −70.5 | 51 | 352 |
| | 47R-3, 50 | 229.50 | −76.1 | 61 | 288 |
| | 48R-4, 82 | 236.32 | −73.2 | 40 | 117 |
| | 49R-2, 89 | 238.39 | −60.9 | 60 | 94 |
| | 50R-4, 87 | 243.37 | −58.4 | 63 | 120 |
| | 51R-1, 102 | 244.02 | −72.9 | 85 | 170 |
| | 52R-4, 69 | 253.19 | −63.1 | 42 | 354 |
| | 53R-3, 15 | 256.15 | −60.2 | 17 | 3 |
| | 54R-3, 125 | 262.25 | −74.5 | 54 | 138 |
| | 54R-5, 117 | 265.17 | −58.0 | −100 | −100 |
| | 55R-3, 130 | 269.30 | −77.5 | 39 | 171 |
| | 56R-2, 11 | 271.61 | −67.0 | 52 | 315 |
| | 56R-2, 144 | 272.94 | 1.9 | 47 | 243 |
| | 57R-2, 135 | 277.85 | 5.0 | 76 | 224 |
| | 58R-2, 33 | 282.33 | −59.3 | −68 | 5 |
| | 59R-3, 70 | 289.20 | 63.0 | 76 | 28 |
| | 60R-1. 18 | 290.68 | 80.9 | 74 | 218 |
| | 61R-1, 81 | 296.31 | 26.2 | 52 | 67 |
| | 62R-3, 104 | 304.54 | 71.8 | 80 | 324 |
| | 63R-3, 80 | 309.30 | 71.0 | 68 | 133 |
| | 63R-6, 28 | 313.28 | −51.7 | 66 | 321 |
| | 64R-2, 54 | 317.04 | −37.7 | 76 | 230 |
| | 65R-2, 67 | 322.17 | 63.4 | 72 | 12 |
| | 66R-2, 86 | 327.36 | 56.5 | 52 | 331 |
| | 66R-3, 134 | 329.34 | −63.0 | −100 | −100 |
| | 68R-3, 15 | 338.15 | −55.5 | 71 | 38 |
| | 69R-4, 138 | 346.88 | 22.3 | 68 | 30 |
| | 70R-1, 105 | 347.05 | 53.5 | 62 | 312 |
| | 71R-2, 82 | 353.32 | −27.9 | 75 | 133 |
| | 72R-3, 36 | 359.36 | 77.5 | 72 | 217 |
| | 72R-6, 106 | 364.56 | −43.9 | 68 | 48 |
| | 73R-3, 73 | 369.23 | 66.7 | 67 | 235 |
| | 74R-2, 38 | 376.88 | 47.4 | 58 | 191 |
| | 74R-6, 41 | 382.91 | −71.2 | 42 | 15 |
| | 75R-3, 48 | 387.98 | −16.0 | 79 | 323 |
| | 75R-6, 75 | 392.75 | −79.2 | 57 | 185 |
| | 76R-3, 50 | 397.50 | −72.1 | 65 | 170 |
| | 77R-4, 70 | 408.70 | −66.3 | 51 | 82 |
| | 78R-4, 65 | 414.65 | −71.4 | 59 | 120 |
| | 79R-2, 65 | 416.65 | −84.6 | 43 | 146 |
| | 79R-7, 99 | 424.49 | −59.8 | 54 | 231 |
| | 80R-1, 131 | 425.31 | −74.8 | 57 | 211 |
| | 80R-7, 23 | 433.23 | −64.6 | 52 | 338 |
| | 81R-2, 54 | 435.54 | −68.1 | 71 | 239 |
| | 81R-7, 64 | 442.84 | −71.0 | −100 | −100 |
| | 82R-2, 13 | 444.63 | −72.2 | 53 | 211 |
| | 82R-6, 11 | 450.61 | −70.4 | 33 | 233 |
| | 83R-4, 95 | 457.95 | −57.1 | 49 | 126 |
| | 83R-7, 104 | 462.54 | −54.5 | 63 | 48 |
| | 84R-2, 67 | 464.17 | −71.7 | 78 | 198 |
| | 84R-3, 14 | 465.14 | −45.6 | 72 | 183 |
| | 85R-4, 9 | 476.09 | −67.8 | 80 | 128 |
| | 85R-7, 17 | 480.67 | −74.1 | 73 | 224 |
| | 86R-6, 143 | 489.93 | −63.9 | 69 | 189 |
| | 87R-5, 20 | 496.70 | −78.7 | 70 | 188 |

Depth is in meters below seafloor, $I_{nrm}$ is the natural remanent inclination in degrees, $I_s$ is the stable inclination in degrees, and Dec is the uncorrected, stable declination in degrees. Values of −100 indicate a directional parameter that could not be obtained for that particular sample.

With the exception of the magnetite-ilmenite gabbros, the $X_0$ values measured in recovered samples agree well with those measured in the borehole with the USGS susceptibility tool (see "Magnetometer Logs" section, this chapter). Although both measurements indicate an increase in magnetic susceptibility within the magnetite-ilmenite-rich gabbros, the values measured *in situ* are substantially lower than those estimated by the overranged susceptibility meter. The nature of this discrepancy will be examined more closely during shore-based studies.

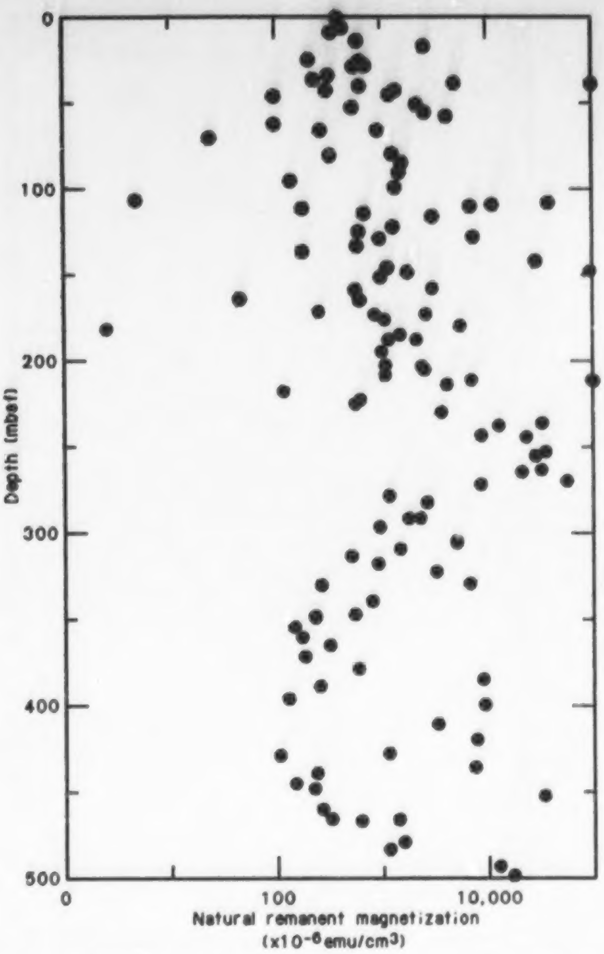

Figure 50. Intensity of natural remanent magnetization (NRM) plotted vs. depth in Hole 735B.

### *Koenigsberger Ratio (Q)*

The Koenigsberger ratio is an estimate of the relative contributions of remanent and induced magnetization within a given rock. It is commonly used to determine whether *in-situ* magnetization is dominated by remanent magnetization ($Q > 1$) or an induced component parallel to the current field ($Q < 1$). $Q$ values are displayed in Figure 52 and show little scatter. Most samples have $Q$ ratios between 1 and 10, which indicates that the *in-situ* magnetization is indeed dominated by a remanent magnetization. Gabbros from both the Troodos ophiolite and the Kane Fracture Zone also show $Q$ ratios ranging between 1 and 10 (Pariso and Johnson, in press; Fox and Opdyke, 1973) and thus agree well with the values observed in Hole 735B gabbros.

### *Alternating Field Demagnetization*

Demagnetization curves were plotted for all samples that were subjected to AFD. From these curves, the peak alternating field required to remove one-half the initial magnetization was determined. This is commonly referred to as the median demagnetizing field (MDF), and these data are displayed in Figure 53. The majority of the samples have high, although scattered, MDF values. However, a large number of samples have very low

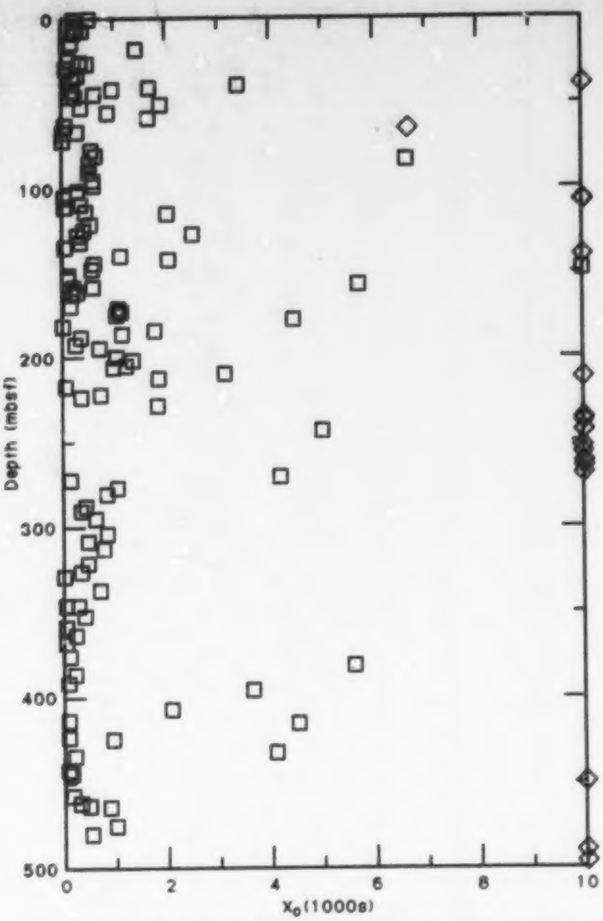

Figure 51. Magnetic susceptibility plotted vs. depth in Hole 735B. Units are $10^{-6}$ cgs. Samples that over-ranged the susceptibility meter are plotted with a diamond symbol and were given a value of 10,000 × $10^{-6}$ cgs, which represents the minimum possible value.

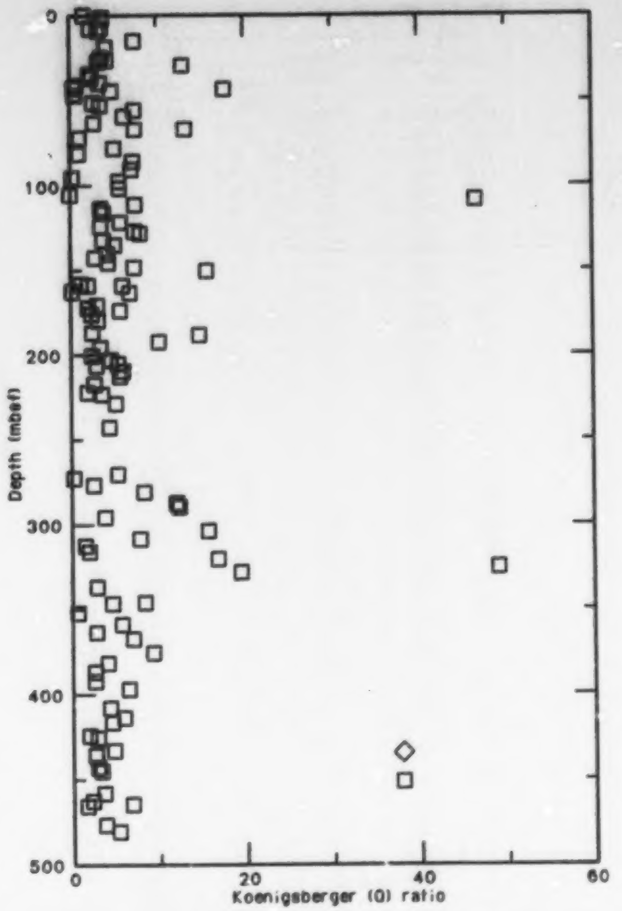

Figure 52. The Koenigsberger ($Q$) ratio plotted vs. depth in Hole 735B using a value of 0.38 Oe for the magnetic field intensity at Site 735.

(<50 Oe) MDF values. The low MDF samples are most often associated with the magnetite- and ilmenite-rich samples.

The demagnetization curves plotted for individual samples commonly fall into one of three shape-based categories. The most frequently observed shape is similar to that displayed in Figure 54 and indicates the gradual removal of a single, stable magnetic vector. In contrast, a large number of samples, particularly those in the magnetite-ilmenite gabbros, exhibit curves similar to that in Figure 55. This type of demagnetization is characterized by the removal of an extremely large component at very low peak fields. The Zijderveld diagram in Figure 55 shows the change in direction of the removed vector, and in such cases, it is always in the direction opposite the stable magnetization. Finally, a significant portion of samples have curves similar to those in Figures 56 and 57. This type of curve is characterized by the easy removal of a small secondary component. Examination of the corresponding Zijderveld diagram shows that this component is usually in the direction opposite the stable magnetization, and thus its removal results in a small, but abrupt, increase in total field magnetization.

### *Thermal Demagnetization*

Stable inclinations were determined in three of the four samples that were thermally demagnetized. Although heating and cooling cycles were performed in air, a short time (a 20-min heating cycle and a 10-min cooling cycle) was spent at elevated temperatures to minimize oxidation. The demagnetization data for two samples are plotted in Figures 58 and 59. Figure 58 shows a three-component system composed of (1) a stable component carried by magnetite, (2) another component probably associated with titanium-poor titanomagnetite, and (3) a weak, viscous component. The remanence of this sample is clearly dominated by a stable component. Figure 59 shows a two-component system having a well-defined stable remanence carried by magnetite and another component roughly opposite to that of the stable component. The secondary and unstable component may be caused by a mineral having a low blocking temperature, such as pyrrhotite or a titanium-rich titanomagnetite.

### *Magnetic Inclinations*

Natural remanent inclinations are plotted vs. depth in Figure 60. The data clearly fall into two groups: one having steep positive inclinations and one having steep negative inclinations. Stable inclinations are plotted vs. depth in Figure 61 and, with the exception of two negative values, are all steep and positive. The two samples having negative stable inclinations were not identified until the working halves of the cores were stored and must be examined further at a later date to explore the possibility that they were misoriented. Average inclination was calculated as 65°

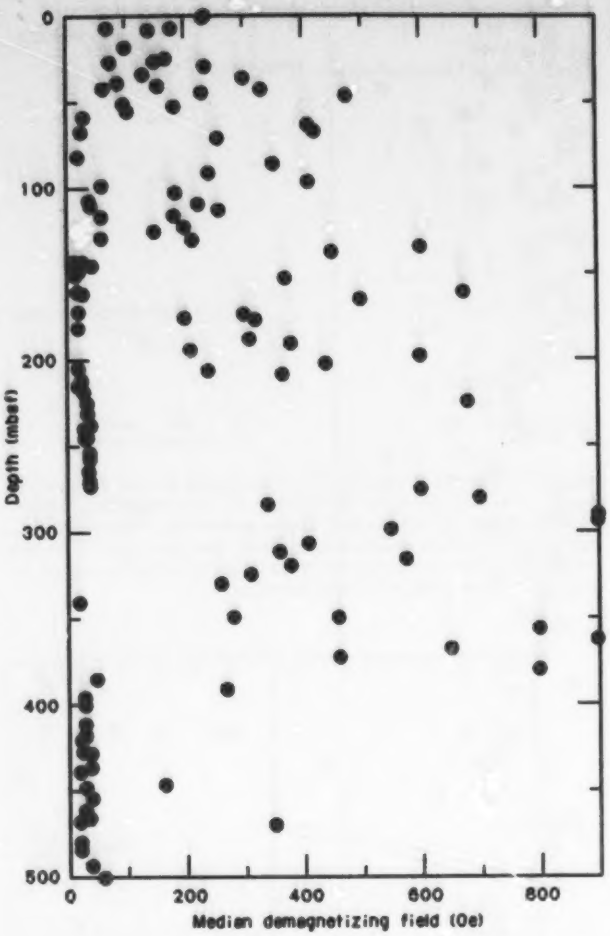

Figure 53. Median demagnetizing field plotted vs. depth in Hole 735B. Units are Oersteds.

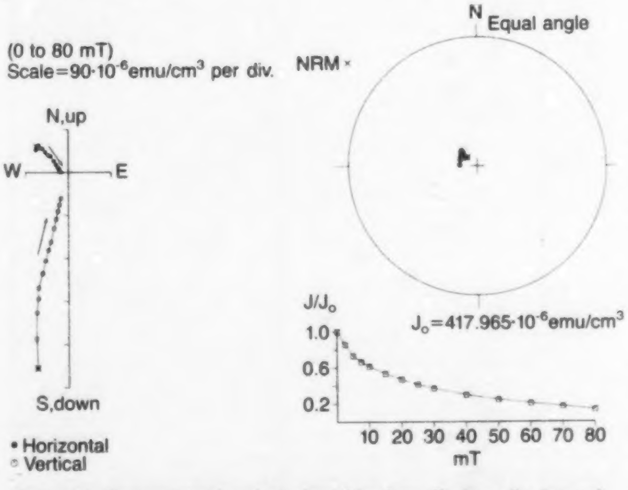

Figure 54. Demagnetization data plotted in three diagrams for interval 118-735B-2D-1, 139-141 cm, Piece 24. The Zijderveld diagram on the left shows no change in magnetic direction during demagnetization, as does the stereographic projection of the total intensity vector on the upper right. The diagram on the lower right is the decay of normalized intensity with increasing peak alternating fields.

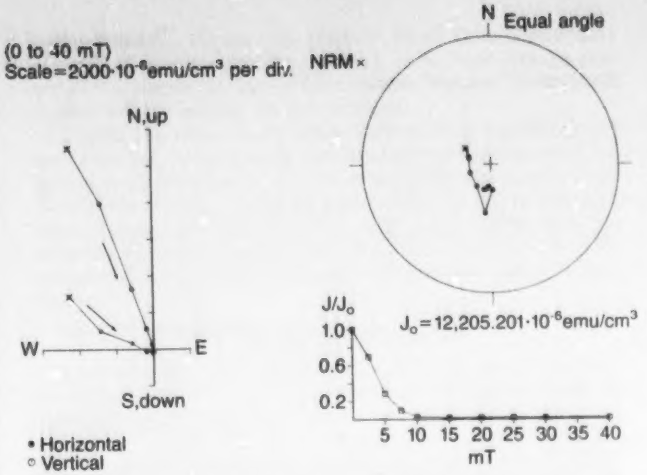

Figure 55. Alternating field demagnetization data plotted in three diagrams for interval 118-735B-86R-6, 14-16 cm, Piece 19. Although the Zijderveld diagram on the left shows only a large, secondary component of magnetization, the change in direction is obvious on the stereographic projection of the total intensity vector on the upper right. In the diagram on the lower right, an abrupt decay in normalized intensity is observed to occur at very low peak alternating fields.

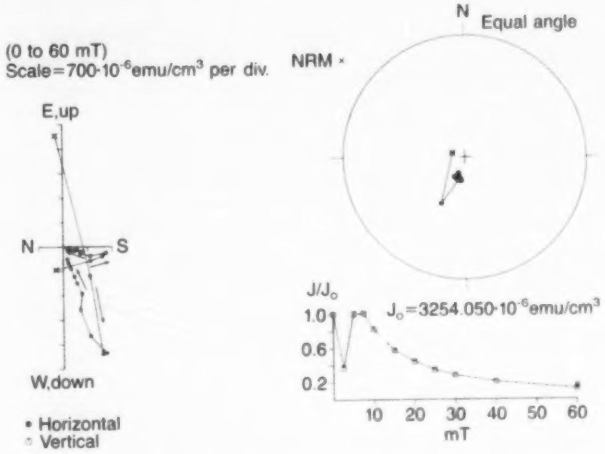

Figure 56. Alternating field demagnetization data plotted in three diagrams for interval 118-735B-33R-4, 27-29 cm, Piece 2B. Two components of almost opposite polarity are observed on the Zijderveld diagram on the left and also on the stereographic projection on the upper right. The figure on the lower right shows an abrupt increase in normalized intensity after removal of the secondary magnetization. This type of curve results in a low MDF, although the coercivity of the stable magnetization appears to be high.

± 7°, using McFaddin and Reid's method (1982). Based upon a geocentric axial dipole, the theoretical inclination for latitude 33°S is −52° and thus the average of the observed inclination is not only reversed but is slightly steeper than expected. Note that logging of the drill hole indicated that it deviates 4° to 6° north from vertical. If this is the case, one might expect a slight shallowing of the true inclination. To clarify this point, further examination of the logging data will be essential. In addition, preliminary examination of the magnetic logging data indicates that all the *in-situ* crustal rocks are of one magnetic polarity. This suggests that the observed negative NRM inclinations may result from a drilling-induced remanence. Again, further exami-

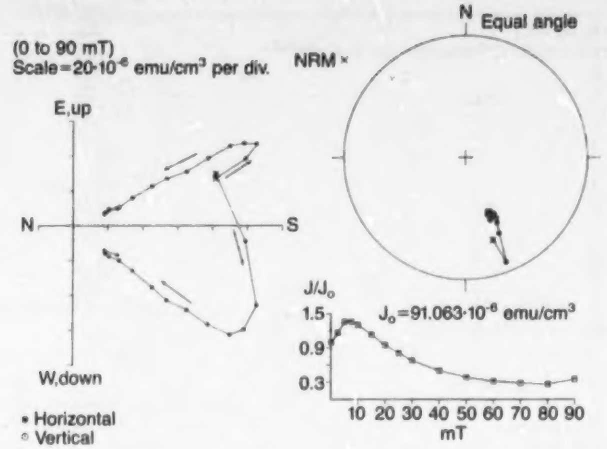

Figure 57. Alternating field demagnetization data plotted in three diagrams for interval 118-735B-16R-1, 139–141 cm, Piece 3H. Two components of almost opposite polarity are observed on the Zijderveld plot on the left and the stereographic projection on the upper right. The curve on the lower right shows an abrupt increase in normalized intensity after removal of the secondary component. This type of curve results in a very high MDF, which therefore is not a good indicator of the coercivity of the primary magnetization.

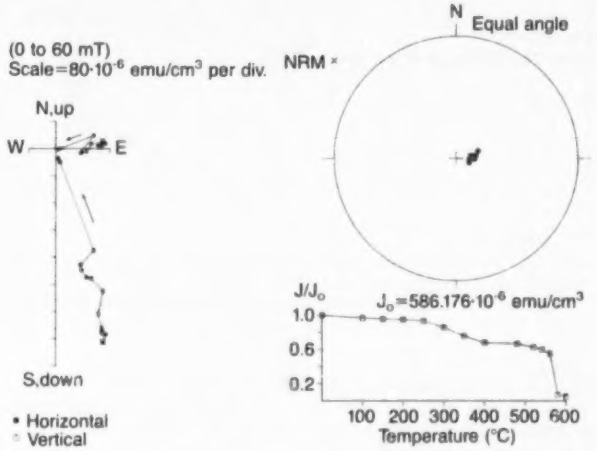

Figure 58. Thermal demagnetization data plotted in three diagrams for Sample 118-735B-3D-1, 60–62 cm, Piece 11. Three weakly defined components appear on the Zijderveld plot on the left, although the stereographic projection on the upper right shows that the total intensity vector changes direction very little. The curve on the lower right also shows three very weakly defined trends from 0° to 250°C, from 250° to 560°C, and from 560° to 580°C.

nation of both the logging and the discrete-sample data will be important for clarifying this point.

## Conclusions

The samples studied vary widely in magnetic properties, but clearly can be divided into two major populations: (1) those having high $J_0$, low MDF, high $X_0$ values, and negative NRM inclinations and (2) those having low $J_0$, high MDF, low $Q$ values, and steep, positive NRM inclinations. Samples of Group 1 clearly possess a very strong but unstable secondary magnetization directed parallel to the present geomagnetic field. The in-

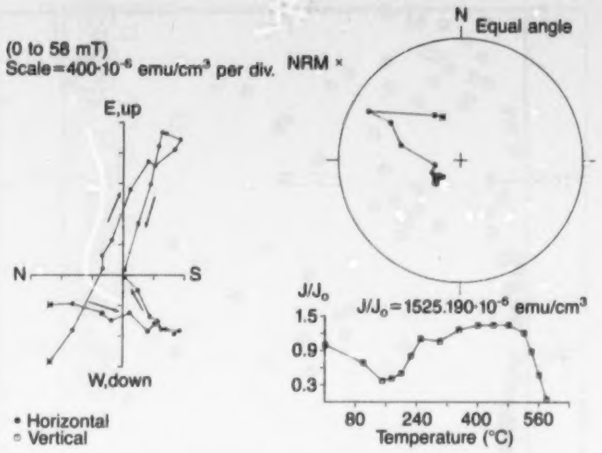

Figure 59. Thermal demagnetization data plotted in three diagrams for Sample 118-735B-38R-4, 28–30 cm, Piece 1C. Two well-defined components of almost opposite polarity appear on both the Zijderveld plot on the left and the stereographic projection on the upper right. The curve on the lower right shows that the removal of the secondary magnetization results in an increase in total intensity.

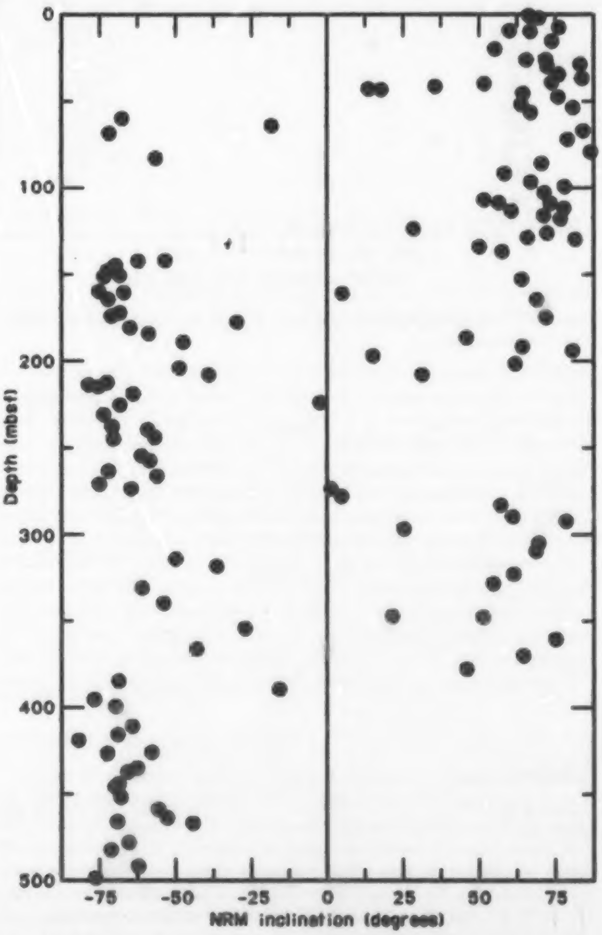

Figure 60. Natural remanent inclinations plotted vs. depth for Hole 735B.

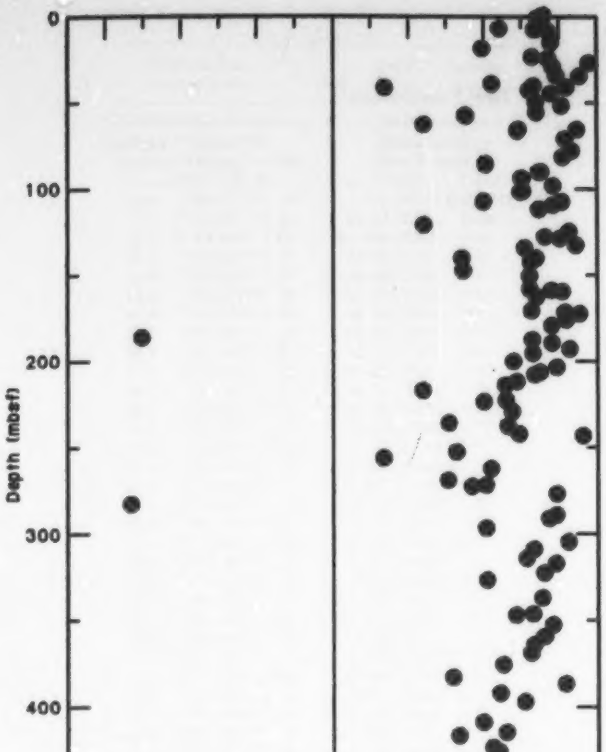

Figure 61. Stable inclinations plotted vs. depth for Hole 735B.

tensity of this magnetization is anomalously high and is clearly associated with the very large concentrations of iron-titanium oxides within these rocks. We are not sure of the source of the secondary magnetization but likely possibilities include (1) a magnetization acquired as a result of the drilling process, such as piezo-remanent magnetization or isothermal remanent magnetization; or (2) viscous remanent magnetization acquired over time in the current field; or (3) magnetization due to secondary alteration (partial thermal remanent magnetization or chemical remanent magnetization). Preliminary analysis of the downhole magnetic logs indicates that the most likely cause is related to drilling.

Although two normal (negative) stable inclinations were observed, the section as a whole clearly has a stable reversed magnetization. A marine magnetic anomaly survey suggests an age of about 12 Ma (anomaly 5A) for the study area (Dick et al., unpublished data). Therefore, the reversed magnetization obtained from this crustal section may be correlated to one of the reversed polarity chrons observed near anomaly 5A. Moreover, because both metamorphosed and unmetamorphosed gabbros of various types have stable positive (reversed) inclinations, a relatively short time interval probably occurred between the initial cooling and metamorphism of these rocks. The remanent intensities are considered large enough to contribute to the marine magnetic anomaly. However, the presence of different magnetic polarities in the vertical section should result in a lower effective intensity. Because the reversals result from a secondary magnetization (as mentioned above), it is important to constrain the source of this magnetization. Further shore-based studies will concentrate on this problem.

Finally, the value of the stable inclination is slightly steeper than expected. If the samples are corrected for inclination of the drill hole (approximately 5°), an even steeper anomalous inclination would result. Although paleosecular variation may have resulted in steeper than expected inclinations, we believe that given the long time required to cool the crustal section, tectonic rotation is a more likely cause for the observed stable inclinations.

## PHYSICAL PROPERTIES

Compressional-wave velocities and index properties were measured for about 180 samples selected as representative of the core obtained at Hole 735B. These data are summarized in Tables 8 through 10. The velocity-density, velocity-porosity and velocity-depth relationships are plotted in Figures 62A, 62B, 63, and 64, and are coded according to rock type. Compressional-wave velocities reflect the component mineral properties and proportions, porosity (especially fracture porosity), and possibly rock texture. Also, $V_p$ can vary with direction in rocks that are layered or that have preferred orientations of cracks or mineral grains, which are themselves anisotropic. All these factors are involved in the suite of rocks studied (Figs. 62A and 62B). Several features of this data set are noteworthy and important and are discussed in detail in the following paragraphs.

1. These crystalline rocks have high seismic velocities (up to 7.28 km/s) and densities (most are greater than 2.9 Mg/m$^3$). Peridotite is the only common rock type having velocities and densities this high. The high velocities and densities occur because these gabbros were variably altered by retrograde metamorphic hydration reactions. A key reason for this is that amphibole is the most abundant alteration mineral. Amphibole ($V_p$ = 6.8–7.0 km/s, density = 3.0–3.2 Mg/m$^3$; Christensen, 1982; Johnson and Olhoeft, 1984) has properties similar to the minerals it replaces, such as clinopyroxene. This contrasts with the low-grade alteration assemblages that include phyllosilicates (such as talc, serpentine, and the micas, with $V_p$ under 6.3 km/s and densities between 2.7 and 2.8 Mg/m$^3$).

2. Metagabbros have the same range of velocities and densities as their igneous gabbroic protoliths (Fig. 62A). In general, this dynamic metamorphism has not changed the mineral assemblages or proportions but has changed grain sizes, grain-grain articulation (grain interrelationships), and mineral crystallographic orientations, none of which was expected to change the average compressional-wave velocities. The observed velocities and densities can be rationalized easily, starting with a basic two-mineral gabbro that consists of plagioclase feldspar (composition = An$_{58}$, $V_p$ = 6.7 km/s, and density = 2.68 Mg/m$^3$) and an augitic clinopyroxene ($V_p$ = 7.22 km/s and density = 3.32 Mg/m$^3$) at a ratio of approximately 60:40. Adding olivine, the most common mineral component ($V_p$ = 8.42 km/s and density = 3.31 Mg/m$^3$), raises *both* $V_p$ and density of the gabbros, whereas ilmenite, the most typical oxide component ($V_p$ = 6 km/s and density = 4.79 Mg/m$^3$), greatly *lowers* $V_p$ and raises density. Most of the oxide-bearing gabbros and their metagabbro derivatives clearly are displaced to the high-density/low-velocity direction of the velocity-density plot in Figure 62A. The maximum observed velocity is 7.27 km/s, which suggests a maximum olivine content of 23%, consistent with that observed in thin section (See "Primary Petrography" section, this chapter).

3. The foliated and/or mylonitized gabbros and metagabbros display varying degrees of $V_p$ anisotropy, depending on the type of foliation developed. Foliated gabbros collected from in-

**Table 8. Index properties of the crystalline rocks recovered from Site 735.**

| Core/section interval (cm) | DIR | Depth (mbsf) | Velocity (km/s) |
|---|---|---|---|
| 118-735B-1D-1, 19–21 | C | 0.19 | 5.53 |
| 1D-1, 141–143 | C | 1.41 | 6.40 |
| 2D-1, 113–115 | C | 7.63 | 5.94 |
| 2D-1, 139–141 | C | 7.89 | 6.38 |
| 2D-1, 142–145 | A | 7.92 | 6.30 |
| 2D-1, 142–145 | B | 7.92 | 6.76 |
| 2D-1, 142–145 | C | 7.92 | 6.69 |
| 2D-2, 99–101 | C | 8.99 | 6.08 |
| 4D-2, 7–9 | C | 19.07 | 6.40 |
| 6D-1, 111–113 | C | 25.11 | 6.66 |
| 7D-1, 74–76 | C | 26.74 | 6.90 |
| 7D-2, 9–11 | C | 27.59 | 7.01 |
| 8D-1, 45–48 | C | 29.65 | 6.75 |
| 9D-1, 120–122 | C | 34.40 | 6.82 |
| 10D-1, 24–26 | C | 36.44 | 6.74 |
| 11D-1, 6–8 | C | 39.26 | 6.52 |
| 12R-1, 36–41 | A | 39.76 | 6.27 |
| 12R-1, 36–41 | C | 39.76 | 6.74 |
| 12R-1, 55–62 | A | 39.95 | 5.55 |
| 12R-1, 55–62 | C | 39.95 | 6.06 |
| 12R-2, 32–34 | A | 41.22 | 6.58 |
| 12R-2, 32–34 | B | 41.22 | 6.70 |
| 12R-2, 32–34 | C | 41.22 | 6.24 |
| 12R-2, 36–38 | C | 41.26 | 6.73 |
| 12R-3, 8–10 | C | 42.48 | 6.90 |
| 12R-3, 77–84 | A | 43.17 | 7.39 |
| 12R-3, 77–84 | C | 43.17 | 6.99 |
| 12R-3, 83–85 | C | 43.23 | 7.19 |
| 13R-1, 91–94 | A | 45.41 | 6.86 |
| 13R-1, 91–94 | B | 45.41 | 6.94 |
| 13R-1, 91–94 | C | 45.41 | 6.94 |
| 13R-1, 102–105 | C | 45.52 | 7.27 |
| 13R-2, 55–58 | C | 46.05 | 7.19 |
| 13R-2, 109–112 | A | 47.09 | 6.48 |
| 13R-2, 109–112 | B | 47.09 | 6.34 |
| 13R-2, 109–112 | C | 47.09 | 6.62 |
| 13R-3, 121–127 | A | 47.21 | 5.75 |
| 13R-3, 121–127 | B | 47.21 | 6.74 |
| 14R-1, 20–26 | A | 51.40 | 6.58 |
| 14R-1, 35–38 | C | 51.55 | 7.04 |
| 14R-2, 22–25 | C | 52.92 | 7.19 |
| 14R-3, 122–128 | A | 55.44 | 6.52 |
| 14R-4, 22–25 | C | 55.92 | 7.20 |
| 15R-2, 128–130 | C | 58.98 | 6.62 |
| 16R-1, 80–86 | A | 62.60 | 5.70 |
| 16R-1, 139–141 | C | 63.19 | 6.69 |
| 16R-4, 34–36 | A | 66.64 | 6.07 |
| 16R-4, 34–36 | B | 66.64 | 6.64 |
| 16R-4, 34–36 | C | 66.64 | 6.53 |
| 16R-4, 77–79 | C | 67.07 | 6.84 |
| 16R-5, 24–26 | C | 68.04 | 6.70 |
| 18R-3, 29–31 | C | 71.79 | 6.87 |
| 19R-1, 138–145 | A | 76.08 | 6.06 |
| 19R-3, 126–133 | A | 78.96 | 6.53 |
| 19R-5, 126–128 | C | 80.96 | 7.14 |
| 20R-1, 17–20 | A | 84.37 | 6.82 |
| 20R-1, 17–20 | B | 84.37 | 6.66 |
| 20R-1, 17–20 | C | 84.37 | 6.82 |
| 20R-2, 54–56 | C | 86.24 | 7.22 |
| 21R-1, 47–50 | A | 89.67 | 5.87 |
| 21R-1, 47–50 | B | 89.67 | 6.44 |
| 21R-1, 47–50 | C | 89.67 | 6.52 |
| 21R-2, 49–51 | C | 91.19 | 5.90 |
| 22R-2, 41–43 | C | 95.91 | 7.14 |
| 22R-3, 118–120 | C | 98.18 | 7.15 |
| 23R-2, 34–36 | C | 102.34 | 7.22 |
| 23R-3, 33–41 | A | 103.83 | 5.68 |
| 23R-4, 120–122 | C | 105.20 | 6.45 |
| 24R-2, 95–97 | C | 107.95 | 6.78 |
| 24R-3, 50–52 | C | 109.00 | 6.69 |
| 24R-4, 26–28 | C | 110.26 | 6.95 |

**Table 8 (continued).**

| Core/section interval (cm) | DIR | Depth (mbsf) | Velocity (km/s) |
|---|---|---|---|
| 118-735B-25R-2, 5–7 | C | 112.05 | 6.61 |
| (Cont.) 25R-3, 42–49 | A | 113.92 | 6.11 |
| 25R-3, 137–139 | C | 114.87 | 7.26 |
| 26R-1, 62–64 | C | 116.12 | 6.92 |
| 26R-3, 64–66 | C | 119.14 | 6.91 |
| 26R-3, 64–66 | B | 119.14 | 6.86 |
| 26R-3, 64–66 | A | 119.14 | 6.78 |
| 27R-1, 84–86 | C | 122.34 | 7.21 |
| 27R-3, 21–29 | A | 123.71 | 6.80 |
| 27R-3, 32–34 | C | 123.82 | 7.11 |
| 28R-1, 22–24 | A | 126.72 | 5.61 |
| 28R-1, 22–24 | B | 126.72 | 6.26 |
| 28R-1, 22–24 | C | 126.72 | 6.10 |
| 28R-2, 12–14 | C | 128.12 | 6.96 |
| 28R-2, 105–113 | A | 129.05 | 6.72 |
| 28R-2, 114–116 | C | 129.14 | 7.17 |
| 29R-2, 46–48 | C | 133.46 | 7.16 |
| 29R-4, 19–21 | C | 136.19 | 6.85 |
| 30R-3, 137–139 | C | 140.87 | 6.18 |
| 30R-4, 14–16 | C | 141.14 | 6.80 |
| 30R-5, 91–93 | C | 143.41 | 6.72 |
| 31R-2, 120–122 | C | 146.20 | 7.03 |
| 31R-4, 118–120 | C | 148.18 | 6.56 |
| 32R-1, 64–66 | C | 149.14 | 6.71 |
| 32R-3, 14–16 | C | 151.64 | 7.05 |
| 33R-1, 93–100 | A | 154.43 | 7.11 |
| 33R-4, 27–29 | C | 158.27 | 6.79 |
| 33R-4, 129–131 | C | 159.29 | 6.57 |
| 34R-1, 103–105 | C | 159.53 | 6.64 |
| 34R-4, 30–32 | C | 163.30 | 6.13 |
| 35R-1, 29–31 | C | 163.79 | 7.21 |
| 35R-2, 11–14 | A | 165.11 | 6.75 |
| 35R-2, 11–14 | B | 165.11 | 6.90 |
| 35R-2, 11–14 | C | 165.11 | 6.89 |
| 35R-5, 131–133 | C | 170.31 | 7.15 |
| 35R-6, 71–74 | A | 171.71 | 6.67 |
| 35R-6, 71–74 | B | 171.71 | 6.73 |
| 35R-6, 71–74 | C | 171.71 | 7.05 |
| 36R-2, 11–13 | C | 172.61 | 7.16 |
| 36R-3, 36–38 | C | 174.36 | 7.12 |
| 37R-1, 11–13 | C | 176.11 | 6.86 |
| 37R-1, 77–83 | A | 176.77 | 6.61 |
| 37R-3, 80–82 | C | 179.80 | 6.86 |
| 38R-2, 15–17 | C | 182.65 | 7.03 |
| 39R-1, 138–141 | A | 187.38 | 7.10 |
| 39R-1, 138–141 | B | 187.38 | 7.25 |
| 39R-1, 138–141 | A | 187.38 | 7.09 |
| 39R-1, 145–147 | C | 187.45 | 6.99 |
| 39R-3, 21–23 | C | 189.21 | 6.11 |
| 40R-2, 62–64 | C | 193.12 | 6.08 |
| 40R-5, 13–15 | C | 197.13 | 6.86 |
| 41R-4, 68–70 | C | 201.18 | 6.90 |
| 42R-2, 119–122 | C | 203.69 | 7.00 |
| 42R-2, 123–130 | A | 203.73 | 6.96 |
| 42R-4, 62–65 | C | 206.12 | 6.90 |
| 43R-1, 126–128 | C | 207.26 | 6.75 |
| 43R-4, 58–61 | A | 211.08 | 6.96 |
| 43R-4, 58–61 | B | 211.08 | 6.90 |
| 43R-4, 58–61 | C | 211.08 | 7.01 |
| 43R-4, 64–66 | C | 211.14 | 6.92 |
| 44R-2, 131–133 | C | 213.81 | 6.71 |
| 44R-4, 102–110 | A | 216.52 | 6.74 |
| 45R-2, 15–17 | C | 217.65 | 7.16 |
| 46R-1, 14–17 | A | 221.14 | 7.04 |
| 46R-1, 14–17 | B | 221.14 | 6.94 |
| 46R-1, 14–17 | C | 221.14 | 6.99 |
| 46R-2, 21–23 | C | 222.71 | 6.90 |
| 46R-2, 120–123 | A | 223.70 | 6.42 |
| 46R-2, 120–123 | B | 223.70 | 6.76 |
| 46R-2, 120–123 | C | 223.70 | 6.77 |
| 46R-2, 128–130 | C | 223.78 | 6.67 |
| 47R-1, 34–41 | A | 226.34 | 6.19 |

Table 8 (continued).

| Core/section interval (cm) | DIR | Depth (mbsf) | Velocity (km/s) |
|---|---|---|---|
| 118-735B-47R-3, 50-52 | C | 229.50 | 7.01 |
| (Cont.) 48R-4, 82-84 | C | 235.32 | 6.64 |
| 49R-1, 53-61 | A | 236.53 | 6.23 |
| 49R-2, 89-91 | C | 238.39 | 6.81 |
| 50R-4, 87-89 | C | 243.37 | 6.62 |
| 51R-1, 52-60 | A | 243.52 | 6.29 |
| 51R-1, 102-104 | C | 244.02 | 6.62 |
| 52R-4, 69-71 | C | 253.19 | 6.82 |
| 53R-2, 15-17 | C | 254.65 | 6.74 |
| 53R-2, 79-82 | A | 255.29 | 6.47 |
| 53R-2, 79-82 | B | 255.29 | 6.56 |
| 53R-2, 79-82 | C | 255.29 | 6.68 |
| 53R-3, 107-110 | A | 257.07 | 6.23 |
| 53R-3, 107-110 | B | 257.07 | 6.49 |
| 53R-3, 107-110 | C | 257.07 | 6.39 |
| 54R-3, 125-127 | C | 262.25 | 6.75 |
| 55R-2, 45-55 | A | 266.95 | 6.19 |
| 55R-3, 130-133 | C | 270.30 | 6.77 |
| 56R-2, 11-14 | C | 271.61 | 6.62 |
| 56R-2, 22-25 | B | 271.72 | 6.76 |
| 56R-2, 22-25 | C | 271.72 | 6.75 |
| 56R-2, 144-146 | C | 272.94 | 6.34 |
| 57R-2, 135-137 | C | 277.85 | 6.90 |
| 57R-3, 23-30 | A | 278.23 | 6.65 |
| 58R-2, 33-35 | C | 282.33 | 6.95 |
| 59R-3, 70-72 | C | 289.20 | 6.91 |
| 59R-3, 126-134 | A | 289.76 | 6.39 |
| 60R-1, 18-20 | C | 290.68 | 7.10 |
| 61R-1, 81-83 | C | 296.31 | 7.10 |
| 62R-3, 104-106 | C | 304.54 | 7.03 |
| 62R-4, 32-39 | A | 305.32 | 6.62 |
| 63R-3, 80-82 | C | 308.80 | 7.02 |
| 63R-6, 28-30 | C | 312.78 | 6.99 |
| 64R-1, 18-24 | A | 315.18 | 6.51 |
| 64R-2, 54-56 | C | 317.04 | 7.06 |
| 65R-2, 67-69 | C | 322.17 | 7.07 |
| 66R-2, 86-88 | C | 327.36 | 6.79 |
| 66R-3, 134-138 | C | 329.34 | 5.95 |
| 67R-3, 79-87 | A | 333.79 | 6.76 |
| 68R-3, 15-17 | C | 338.15 | 6.99 |
| 69R-4, 138-140 | C | 346.88 | 7.15 |
| 70R-1, 105-107 | C | 347.05 | 6.13 |
| 71R-2, 50-57 | A | 353.00 | 6.78 |
| 71R-2, 82-84 | C | 353.32 | 7.13 |
| 72R-2, 90-98 | A | 358.40 | 6.86 |
| 72R-3, 36-38 | C | 359.36 | 7.25 |
| 72R-6, 106-108 | C | 364.56 | 7.09 |
| 73R-3, 73-75 | C | 369.23 | 7.17 |
| 73R-5, 120-126 | A | 372.70 | 5.55 |
| 74R-6, 41-43 | C | 382.91 | 6.47 |
| 75R-3, 48-50 | C | 387.98 | 7.15 |
| 75R-5, 31-38 | A | 390.81 | 7.01 |
| 75R-6, 75-77 | C | 392.75 | 7.20 |
| 76R-3, 50-52 | C | 397.50 | 6.87 |
| 76R-6, 21-28 | A | 401.71 | 6.83 |
| 77R-2, 91-100 | A | 405.91 | 6.52 |
| 77R-3, 52-55 | A | 407.05 | 6.49 |
| 77R-3, 52-55 | B | 407.05 | 6.83 |
| 77R-3, 52-55 | C | 407.05 | 6.83 |
| 77R-4, 70-72 | C | 408.70 | 6.91 |
| 78R-4, 65-67 | C | 414.65 | 7.22 |
| 79R-2, 64-67 | C | 416.64 | 6.97 |
| 79R-7, 99-102 | C | 423.49 | 7.27 |
| 80R-1, 131-133 | C | 425.31 | 6.74 |
| 80R-7, 23-25 | C | 432.23 | 6.79 |
| 81R-2, 54-56 | C | 435.54 | 7.09 |
| 81R-3, 142-150 | A | 437.92 | 6.61 |
| 81R-7, 64-66 | C | 442.14 | 7.17 |
| 82R-2, 13-15 | C | 444.63 | 7.07 |
| 82R-6, 11-13 | C | 450.61 | 6.72 |
| 83R-4, 95-97 | C | 457.95 | 7.09 |
| 83R-7, 104-106 | C | 461.54 | 6.94 |
| 84R-2, 67-69 | C | 464.17 | 5.73 |
| 84R-3, 14-16 | C | 465.14 | 7.06 |
| 85R-4, 9-11 | C | 476.09 | 6.34 |
| 85R-5, 15-17 | A | 477.65 | 5.99 |
| 118-735B-85R-5, 15-17 | B | 477.65 | 6.56 |
| (Cont.) 85R-5, 15-17 | C | 477.65 | 6.53 |
| 85R-7, 17-19 | C | 479.67 | 6.85 |
| 86R-4, 24-34 | A | 485.74 | 6.60 |
| 86R-6, 143-145 | C | 489.93 | 6.60 |
| 87R-5, 15-17 | A | 496.65 | 5.99 |
| 87R-5, 15-17 | B | 496.65 | 6.56 |
| 87R-5, 15-17 | C | 496.65 | 6.53 |
| 87R-5, 20-23 | C | 496.70 | 6.34 |

DIR = propagation and vibration directions of *P*-wave where A = Direction normal to foliation; B = direction parallel to lineation; C = direction perpendicular to lineation and parallel to foliation. Aluminum standard used for calibration purposes at the end of velocity measurements (standard velocity 6295 m/s).

tervals having igneous textures tend to be isotropic (Table 10), whereas metagabbros having porphyroclastic or mylonitic textures can transmit *P* waves as much as 11.4% faster in the lineation direction, compared to that perpendicular to foliation. Both plagioclase feldspar and clinopyroxene display marked $V_p$ anisotropy ($V_p$(max)/$V_p$(min) = 1.26 and 1.23, respectively; Christensen, 1982), and thus a relatively modest preferred orientation can lead to significant velocity anisotropy. Evidently, magmatic processes do not produce significant preferred orientations. This interpretation may be tested using universal-stage techniques.

Velocities in the metagabbro tectonites of Hole 735B are very directional and have an average velocity of 6.3 km/s and anisotropy ranging from 1.8% to 11.4%. Velocity is always slowest perpendicular to foliation and generally fastest in the direction of lineation. This anisotropy probably stems from the mineral-orienting mechanisms that operate during *in-situ* inelastic deformation. Preliminary inspection of thin sections of some of the tectonite samples confirms the presence of plagioclase and clinopyroxene having preferred orientations. Some of the porphyroclastic metagabbros are banded and have elongated pyroxene porphyroclasts enclosed in a matrix of fine granular plagioclase feldspar. Such banding can also cause velocity anisotropy (see review by Crampin, 1981). Those sources of velocity anisotropy should be investigated during future work using these samples.

A number of altered rocks have velocities that are significantly lower than those expected for plagioclase feldspar plus clinopyroxene ± olivine ± oxide assemblages. Nearly all of these are altered gabbroic rocks or vein fillings having high porosities (Fig. 63). A few rocks have a high proportion of phyllosilicates, which should lower their velocities. Most of the low $V_p$ rocks have high porosities, presumably because of networks of interconnected microfractures. Porosity markedly lowers $V_p$ in rocks (Christensen, 1982), which appears to be the principal reason why some of the rocks from Hole 735B have low $V_p$. This hypothesis can be tested by measuring velocity at pressure, which closes up fracture porosity and raises $V_p$ to values nearer the component mineral grain velocities.

One of our objectives was to compare the compressional-wave velocities in the core with the sonic and vertical seismic profile (VSP) logs in the borehole. Figure 64 is a plot of $V_p$ vs. depth for Hole 735B, based on our measurements. This portrayal of $V_p$ with depth is presently inadequate for a number of reasons. First, even though the sampling density was unprece-

Table 9. Index properties of the crystalline rocks recovered from Site 735.

| Core/section interval (cm) | Bulk density (Mg/m$^3$) | Porosity (%) | Water content (%) | Grain density (Mg/m$^3$) | Void ratio | Dry-bulk density (Mg/m$^3$) |
|---|---|---|---|---|---|---|
| 118-735B-1D-1, 19-21 | 2.938 | 2.9 | 1.0 | 2.940 | 0.03 | 2.909 |
| 1D-1, 141-143 | 2.945 | 1.5 | 0.5 | 2.920 | 0.02 | 2.930 |
| 2D-1, 113-115 | 3.103 | 4.1 | 1.4 | 3.102 | 0.04 | 3.061 |
| 2D-1, 139-141 | 2.924 | 2.0 | 0.7 | 2.918 | 0.02 | 2.904 |
| 2D-2, 99-101 | 2.947 | 1.2 | 0.4 | 2.920 | 0.01 | 2.934 |
| 4D-2, 7-9 | 2.876 | 1.2 | 0.4 | 2.876 | 0.01 | 2.864 |
| 6D-1, 111-113 | 2.900 | 0.9 | 0.3 | 2.891 | 0.01 | 2.890 |
| 7D-1, 74-76 | 2.961 | 0.4 | 0.1 | 2.956 | 0.00 | 2.957 |
| 7D-2, 9-11 | 3.001 | 0.2 | 0.1 | 3.017 | 0.00 | 2.998 |
| 8D-1, 45-48 | 2.891 | 0.7 | 0.3 | 2.884 | 0.01 | 2.883 |
| 9D-1, 120-122 | 2.969 | 0.9 | 0.3 | 2.971 | 0.01 | 2.960 |
| 10D-1, 24-26 | 3.019 | 0.4 | 0.1 | 3.035 | 0.00 | 3.015 |
| 11D-1, 6-8 | 3.173 | 0.7 | 0.2 | 3.195 | 0.01 | 3.166 |
| 12R-2, 36-38 | 2.959 | 0.6 | 0.2 | 2.954 | 0.01 | 2.952 |
| 12R-3, 8-10 | 2.905 | 0.2 | 0.1 | 2.886 | 0.00 | 2.903 |
| 12R-3, 83-85 | 2.996 | 0.3 | 0.1 | 2.973 | 0.00 | 2.993 |
| 13R-1, 102-105 | 2.966 | 0.1 | 0.1 | 2.959 | 0.00 | 2.965 |
| 13R-2, 55-58 | 2.889 | 0.2 | 0.1 | 2.897 | 0.00 | 2.887 |
| 14R-1, 35-38 | 3.010 | 0.5 | 0.2 | 3.024 | 0.00 | 3.005 |
| 14R-2, 22-25 | 3.027 | −0.2 | −0.1 | 3.007 | 0.00 | 3.029 |
| 14R-4, 22-25 | 2.956 | 0.2 | 0.1 | 2.991 | 0.00 | 2.954 |
| 15R-2, 128-130 | 2.878 | 0.4 | 0.1 | 2.856 | 0.00 | 2.873 |
| 16R-1, 139-141 | 2.920 | 0.8 | 0.3 | 2.911 | 0.01 | 2.912 |
| 16R-4, 77-79 | 2.926 | 1.0 | 0.4 | 2.929 | 0.01 | 2.916 |
| 16R-5, 24-26 | 2.922 | 0.0 | 0.0 | 2.916 | 0.00 | 2.921 |
| 18R-3, 29-31 | 2.927 | 0.3 | 0.1 | 2.925 | 0.00 | 2.924 |
| 19R-5, 126-128 | 2.859 | −0.1 | 0.0 | 2.866 | 0.00 | 2.860 |
| 20R-2, 54-56 | 2.949 | 0.3 | 0.1 | 2.950 | 0.00 | 2.946 |
| 21R-2, 49-51 | 2.821 | 4.5 | 1.6 | 2.809 | 0.05 | 2.775 |
| 22R-2, 41-43 | 2.953 | 0.4 | 0.2 | 2.943 | 0.00 | 2.948 |
| 22R-3, 118-120 | 2.912 | 0.7 | 0.2 | 2.910 | 0.01 | 2.905 |
| 23R-2, 34-36 | 2.945 | 0.5 | 0.2 | 2.937 | 0.00 | 2.940 |
| 23R-4, 120-122 | 2.955 | 1.7 | 0.6 | 2.930 | 0.02 | 2.938 |
| 24R-2, 95-97 | 3.350 | 1.0 | 0.3 | 3.392 | 0.01 | 3.339 |
| 24R-3, 50-52 | 3.132 | 1.1 | 0.3 | 3.110 | 0.01 | 3.121 |
| 24R-4, 26-28 | 2.975 | 0.7 | 0.2 | 2.991 | 0.01 | 2.968 |
| 25R-2, 5-7 | 2.928 | 1.6 | 0.6 | 2.920 | 0.02 | 2.912 |
| 25R-3, 137-139 | 2.967 | 0.0 | 0.0 | 2.964 | 0.00 | 2.967 |
| 26R-1, 62-64 | 2.925 | 0.2 | 0.1 | 2.928 | 0.00 | 2.923 |
| 27R-1, 84-86 | 3.005 | 0.6 | 0.2 | 3.009 | 0.01 | 3.000 |
| 27R-3, 32-34 | 2.893 | 0.4 | 0.2 | 2.894 | 0.00 | 2.889 |
| 28R-2, 12-14 | 3.033 | 0.6 | 0.2 | 3.013 | 0.01 | 3.026 |
| 28R-2, 114-116 | 2.974 | 0.5 | 0.2 | 2.986 | 0.00 | 2.970 |
| 29R-2, 46-48 | 2.952 | 0.3 | 0.1 | 2.945 | 0.00 | 2.948 |
| 29R-4, 19-21 | 2.928 | 1.0 | 0.3 | 2.919 | 0.01 | 2.918 |
| 30R-3, 137-139 | 3.271 | 2.3 | 0.7 | 3.274 | 0.02 | 3.247 |
| 30R-4, 14-16 | 2.876 | 0.5 | 0.2 | 2.882 | 0.01 | 2.871 |
| 30R-5, 91-93 | 2.917 | 0.4 | 0.2 | 2.879 | 0.00 | 2.912 |
| 31R-2, 120-122 | 2.942 | 0.4 | 0.2 | 2.930 | 0.00 | 2.937 |
| 31R-4, 118-120 | 2.890 | 2.4 | 0.8 | 2.872 | 0.02 | 2.866 |
| 32R-1, 64-66 | 4.083 | 0.9 | 0.2 | 4.061 | 0.01 | 4.074 |
| 32R-3, 14-16 | 2.894 | 0.4 | 0.2 | 2.903 | 0.00 | 2.889 |
| 33R-4, 27-29 | 2.870 | 0.5 | 0.2 | 2.866 | 0.00 | 2.865 |
| 33R-4, 129-131 | 2.930 | 0.3 | 0.1 | 2.897 | 0.00 | 2.927 |
| 34R-1, 103-105 | 2.969 | 0.2 | 0.1 | 2.963 | 0.00 | 2.967 |
| 34R-4, 30-32 | 2.991 | 2.4 | 0.8 | 3.018 | 0.02 | 2.966 |
| 35R-1, 29-31 | 2.972 | 0.1 | 0.0 | 2.949 | 0.00 | 2.971 |
| 35R-5, 131-133 | 2.989 | 0.0 | 0.0 | 2.979 | 0.00 | 2.989 |
| 36R-2, 11-13 | 2.913 | 0.1 | 0.0 | 2.907 | 0.00 | 2.912 |
| 36R-3, 36-38 | 2.935 | 0.4 | 0.1 | 2.937 | 0.00 | 2.930 |
| 37R-1, 11-13 | 2.927 | 0.6 | 0.2 | 2.931 | 0.01 | 2.921 |
| 37R-3, 82-84 | 3.065 | 0.9 | 0.3 | 3.041 | 0.01 | 3.055 |
| 38R-2, 15-17 | 2.962 | 0.6 | 0.2 | 2.952 | 0.01 | 2.956 |
| 38R-4, 28-30 | 2.981 | 0.4 | 0.1 | 3.087 | 0.00 | 2.977 |
| 39R-1, 145-147 | 2.958 | 0.5 | 0.2 | 2.968 | 0.00 | 2.953 |
| 39R-3, 21-23 | 2.871 | 2.1 | 0.8 | 2.819 | 0.02 | 2.849 |
| 40R-2, 62-64 | 2.895 | 2.4 | 0.9 | 2.881 | 0.03 | 2.870 |

dented for a 0.5-km hard-rock hole (averaging 1 sample every 3–5 m), the rich variation of lithologies with depth makes this sampling inadequate. The clear relationships between mineralogy and porosity on one side and velocity and density on the other, as described above, will allow us eventually to construct a synthetic velocity profile when the detailed lithologic log is finished. A second limitation is that the pressure increases to approximately 22 MPa at the bottom of the hole, including the pressure of the water column. This will increase $V_p$ for the lower porosity rocks by closing porosity, especially fracture porosity. This will be corrected during shore-based studies by measuring $V_p$ at elevated pressure. Third, our samples are a maximum 70 mm long and do not contain macroscopic fractures. Large-scale *in-situ* fractures may substantially lower *in-situ* $V_p$. Com-

Table 9 (continued).

| Core/section interval (cm) | Bulk density (Mg/m$^3$) | Porosity (%) | Water content (%) | Grain density (Mg/m$^3$) | Void ratio | Dry-bulk density (Mg/m$^3$) |
|---|---|---|---|---|---|---|
| 118-735B-40R-5, 13-15 | 2.915 | 0.6 | 0.2 | 2.928 | 0.01 | 2.909 |
| (Cont). 41R-4, 68-70 | 2.930 | 0.5 | 0.2 | 2.919 | 0.00 | 2.925 |
| 42R-2, 119-122 | 2.930 | 0.5 | 0.2 | 2.946 | 0.01 | 2.925 |
| 42R-4, 62-65 | 2.947 | 0.6 | 0.2 | 2.923 | 0.01 | 2.940 |
| 43R-1, 126-128 | 2.981 | 0.4 | 0.1 | 2.983 | 0.00 | 2.977 |
| 43R-4, 64-66 | 3.033 | 1.0 | 0.3 | 3.024 | 0.01 | 3.023 |
| 44R-2, 131-133 | 2.978 | 1.2 | 0.4 | 2.948 | 0.01 | 2.965 |
| 45R-2, 15-17 | 2.942 | 0.8 | 0.3 | 2.925 | 0.01 | 2.934 |
| 46R-2, 21-23 | 2.996 | 0.9 | 0.3 | 2.987 | 0.01 | 2.986 |
| 46R-2, 128-130 | 2.952 | 1.4 | 0.5 | 2.921 | 0.01 | 2.938 |
| 47R-3, 50-52 | 2.998 | 0.5 | 0.2 | 3.004 | 0.01 | 2.993 |
| 48R-4, 82-84 | 3.255 | 0.8 | 0.3 | 3.265 | 0.01 | 3.247 |
| 49R-2, 89-91 | 3.298 | 0.4 | 0.1 | 3.272 | 0.00 | 3.294 |
| 50R-4, 87-89 | 2.957 | 0.7 | 0.3 | 2.931 | 0.01 | 2.949 |
| 51R-1, 102-104 | 3.083 | 0.7 | 0.2 | 3.058 | 0.01 | 3.075 |
| 52R-4, 69-71 | 3.164 | 0.6 | 0.2 | 3.168 | 0.01 | 3.159 |
| 53R-3, 15-17 | 3.144 | 0.7 | 0.2 | 3.139 | 0.01 | 3.136 |
| 54R-3, 125-127 | 3.283 | 0.6 | 0.2 | 3.288 | 0.01 | 3.277 |
| 54R-5, 117-119 | 3.171 | 0.5 | 0.1 | 3.179 | 0.00 | 3.166 |
| 55R-3, 130-133 | 3.257 | 0.2 | 0.1 | 3.240 | 0.00 | 3.254 |
| 56R-1, 11-14 | 3.155 | 0.1 | 0.0 | 3.150 | 0.00 | 3.154 |
| 56R-2, 144-146 | 3.189 | 0.8 | 0.3 | 3.169 | 0.01 | 3.181 |
| 57R-2, 135-138 | 2.921 | 0.3 | 0.1 | 2.900 | 0.00 | 2.918 |
| 58R-2, 33-35 | 2.864 | 0.1 | 0.0 | 2.841 | 0.00 | 2.862 |
| 59R-3, 70-72 | 3.013 | 0.2 | 0.1 | 3.014 | 0.00 | 3.011 |
| 60R-1, 18-20 | 2.990 | 0.2 | 0.1 | 2.986 | 0.00 | 2.988 |
| 61R-1, 81-83 | 2.990 | 0.2 | 0.1 | 2.974 | 0.00 | 2.988 |
| 62R-3, 104-106 | 3.000 | 0.2 | 0.1 | 3.013 | 0.00 | 2.998 |
| 63R-3, 80-82 | 2.925 | 0.4 | 0.1 | 2.897 | 0.00 | 2.921 |
| 63R-6, 28-30 | 2.930 | 0.3 | 0.1 | 2.917 | 0.00 | 2.927 |
| 64R-2, 54-56 | 3.017 | 0.3 | 0.1 | 3.010 | 0.00 | 3.013 |
| 65R-2, 67-69 | 3.022 | 0.6 | 0.2 | 2.960 | 0.01 | 3.016 |
| 66R-2, 86-88 | 2.923 | 0.9 | 0.3 | 2.981 | 0.01 | 2.914 |
| 66R-3, 134-138 | 2.931 | 4.9 | 1.7 | 2.961 | 0.05 | 2.882 |
| 68R-3, 15-17 | 2.937 | 0.3 | 0.1 | 2.936 | 0.00 | 2.934 |
| 69R-4, 138-140 | 2.985 | 0.2 | 0.1 | 2.970 | 0.00 | 2.983 |
| 70R-1, 105-107 | 2.776 | 2.4 | 0.9 | 2.765 | 0.02 | 2.752 |
| 71R-2, 82-84 | 2.929 | 0.1 | 0.0 | 2.936 | 0.00 | 2.928 |
| 72R-3, 36-38 | 2.987 | 0.1 | 0.0 | 2.997 | 0.00 | 2.986 |
| 72R-6, 106-108 | 2.968 | 0.2 | 0.1 | 2.981 | 0.00 | 2.966 |
| 73R-3, 73-75 | 3.021 | 0.1 | 0.0 | 3.021 | 0.00 | 3.021 |
| 74R-6, 41-43 | 3.054 | 0.4 | 0.1 | 2.927 | 0.00 | 3.050 |
| 75R-3, 48-50 | 2.995 | 0.3 | 0.1 | 2.994 | 0.00 | 2.992 |
| 75R-6, 75-77 | 2.948 | 0.1 | 0.0 | 2.937 | 0.00 | 2.947 |
| 76R-3, 50-52 | 2.988 | 0.6 | 0.2 | 2.981 | 0.01 | 2.982 |
| 77R-4, 70-72 | 2.990 | 0.3 | 0.1 | 2.999 | 0.00 | 2.987 |
| 78R-4, 65-67 | 3.004 | 0.2 | 0.1 | 2.962 | 0.00 | 3.002 |
| 79R-2, 64-67 | 3.108 | 0.2 | 0.1 | 3.106 | 0.00 | 3.106 |
| 79R-7, 99-102 | 2.932 | 0.2 | 0.1 | 2.937 | 0.00 | 2.930 |
| 80R-1, 131-133 | 3.046 | 0.4 | 0.1 | 3.049 | 0.00 | 3.042 |
| 80R-7, 23-25 | 3.222 | 0.3 | 0.1 | 3.213 | 0.00 | 3.220 |
| 81R-2, 54-56 | 2.959 | 0.2 | 0.1 | 2.960 | 0.00 | 2.957 |
| 81R-7, 64-66 | 2.971 | 0.2 | 0.1 | 2.978 | 0.00 | 2.970 |
| 82R-2, 13-15 | 2.906 | 0.1 | 0.0 | 2.905 | 0.00 | 2.905 |
| 82R-6, 11-13 | 3.201 | 0.5 | 0.2 | 3.193 | 0.00 | 3.196 |
| 83R-4, 95-97 | 2.995 | 0.2 | 0.1 | 2.981 | 0.00 | 2.993 |
| 83R-7, 104-106 | 3.121 | 0.4 | 0.1 | 3.103 | 0.00 | 3.117 |
| 84R-2, 67-69 | 2.816 | 1.6 | 0.6 | 2.818 | 0.02 | 2.800 |
| 84R-3, 14-16 | 2.963 | 0.1 | 0.0 | 2.947 | 0.00 | 2.963 |
| 85R-4, 9-11 | 2.929 | 0.6 | 0.2 | 2.932 | 0.01 | 2.922 |
| 85R-7, 17-19 | 2.864 | 0.0 | 0.0 | 2.879 | 0.00 | 2.864 |
| 86R-6, 143-145 | 2.917 | 0.5 | 0.2 | 2.917 | 0.01 | 2.911 |
| 87R-5, 20-22 | 3.148 | 1.2 | 0.4 | 3.124 | 0.01 | 3.135 |

Bulk density = wet weight/wet volume, grain density = dry weight/dry volume, void ratio = pore space/volume sample (including salt content), dry bulk density = dry weight/wet volume.

parison of the velocity logs with our core-based profile should help guide us concerning the distribution and widths of open fractures around the borehole (see also "Borehole Televiewer" section, this chapter). Many of the fractures observed in the core were filled, typically with amphiboles. As indicated in the section above, amphiboles have high velocities, and such fracture filling probably will diminish the effect of fractures for reducing $V_p$.

Despite the above limitations of the raw velocity profile of Figure 64, some gross features stand out. First, the rapid increase in velocities from the seafloor to about 40 mbsf correlates well with the greater degree of alteration and higher fracture po-

**Table 10. Directional compressional-wave velocities measured using cube samples.**

| Core/section interval (cm) | Velocity[1] (km/s) | | | Anisot.[2] index, % | Rock type |
|---|---|---|---|---|---|
| | A | B | C | | |
| 118-735B-2D-1, 142–145 | 6.29 | 6.76 | 6.69 | 7.5 | Mylonitic metagabbro |
| 12R-2, 32–34 | 6.58 | 6.70 | 6.24 | 1.8 | Porphyroclastic metagabbro |
| 13R-1, 91–94 | 6.86 | 6.94 | 6.94 | 1.2 | Foliated gabbro |
| 13R-2, 109–112 | 6.47 | 6.34 | 6.62 | 0.0 | Foliated gabbro |
| 16R-4, 34–36 | 6.06 | 6.64 | 6.53 | 9.6 | Mylonitic metagabbro |
| 20R-1, 17–20 | 6.81 | 6.66 | 6.82 | −2.2 | Foliated olivine gabbro |
| 21R-1, 47–50 | 5.87 | 6.64 | 6.52 | 9.7 | Foliated metagabbro |
| 26R-3, 64–66 | 6.91 | 6.86 | 6.78 | −0.7 | Foliated olivine gabbro |
| 28R-1, 22–24 | 5.61 | 6.26 | 6.09 | 11.4 | Mylonitic metagabbro |
| 35R-2, 11–14 | 6.75 | 6.90 | 6.89 | 2.2 | Porphyroclastic oliv. gabbro |
| 35R-6, 7–74 | 6.67 | 6.73 | 7.05 | 0.9 | Porphyroclastic metagabbro |
| 39R-1, 138–141 | 7.10 | 7.25 | 7.09 | 2.1 | Foliated gabbro |
| 43R-4, 58–61 | 6.96 | 6.90 | 7.01 | −0.9 | Foliated olivine gabbro |
| 46R-1, 14–17 | 7.04 | 6.93 | 6.99 | −1.6 | Foliated gabbro |
| 46R-2, 120–123 | 6.42 | 6.76 | 6.77 | 5.3 | Porphyroclastic metagabbro |
| 53R-2, 79–82 | 6.47 | 6.56 | 6.78 | 1.4 | Foliated oxide gabbro |
| 53R-3, 107–110 | 6.23 | 6.49 | 6.39 | 4.2 | Foliated oxide gabbro |
| 56R-2, 22–25 | 6.56 | 6.76 | 6.75 | 3.0 | Mylonitic oxide metagabbro |
| 77R-3, 52–55 | 6.49 | 6.83 | 6.83 | 5.2 | Mylonitic metagabbro |
| 85R-5, 15–17 | 5.99 | 6.55 | 6.53 | 9.3 | Mylonitic metagabbro |

[1] A = direction normal to foliation; B = direction parallel to lineation; C = direction perpendicular to lineation and parallel to foliation.

[2] Anisotropy index = $(V_A - V_B)/V_A$.

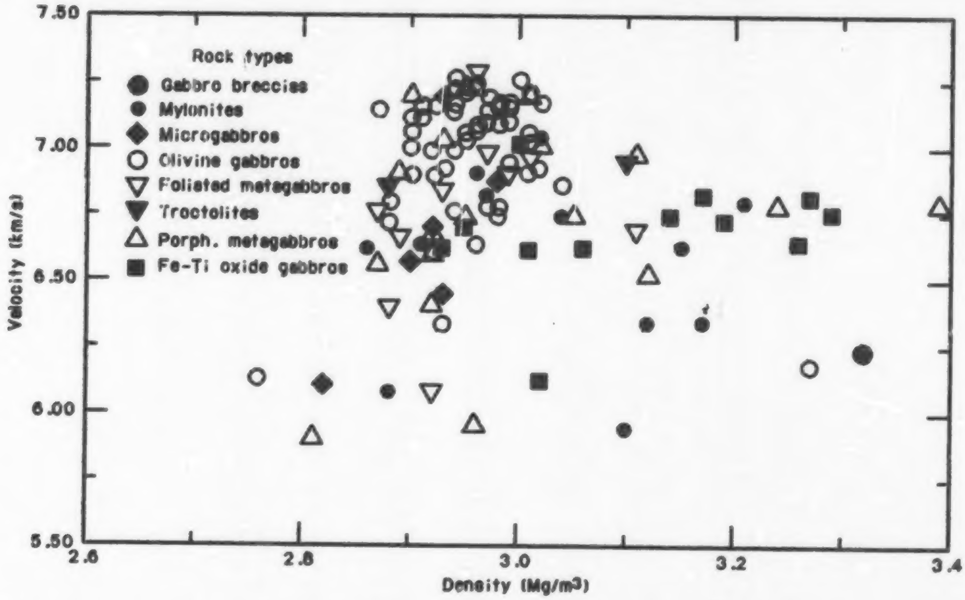

Figure 62. Velocity-density relationships for the rocks of Hole 735B, coded according to rock type. Nominally fresh rocks. Note the clustering of data at $V_p$ = 7.0 km/s and density = 2.95 Mg/m$^3$ for olivine gabbros and metagabbros, which is consistent with the mineral proportions and properties.

rosities in the rocks of lithologic Unit I, and with the lower apparent $V_p$ evident from the traveltime curves in the VSP study (see "Vertical Seismic Profiling" section, this chapter). Second, the oxide-rich gabbros and metagabbros of lithologic Unit IV (see "Lithostratigraphy" section, this chapter) clearly produce a dip in velocity and a sharp increase in density (Table 9). This lithologic unit also correlates well with a marked increase in the NRM (see "Paleomagnetics" section, this chapter) and reduction in electrical resistivity (see "Schlumberger Logs" section, this chapter). Third, the velocities indicated in Figure 64 include 34 measurements of $V_p$ along the original vertical direction in half-core samples, averaging 6.5 km/s compared with 7.0 km/s for measurements having horizontal propagation directions. The VSP experiments indicate that the hole-averaged vertical $V_p$ = 6.55 ± 0.15 km/s, which corresponds well with the hole-averaged vertical $V_p$ measurements cited above. Inversions of marine seismic-refraction traveltime data indicate that $V_p$ for layer 3 is 6.8 ± 0.2 km/s for near-horizontal propagation directions (Fox and Stroup, 1981), which compares well with our hole-averaged horizontal $V_p$ measurements from core samples. This vertical vs. horizontal $V_p$ anisotropy is significant and parallels *in-situ* VSP and seismic-refraction observations. Other fine struc-

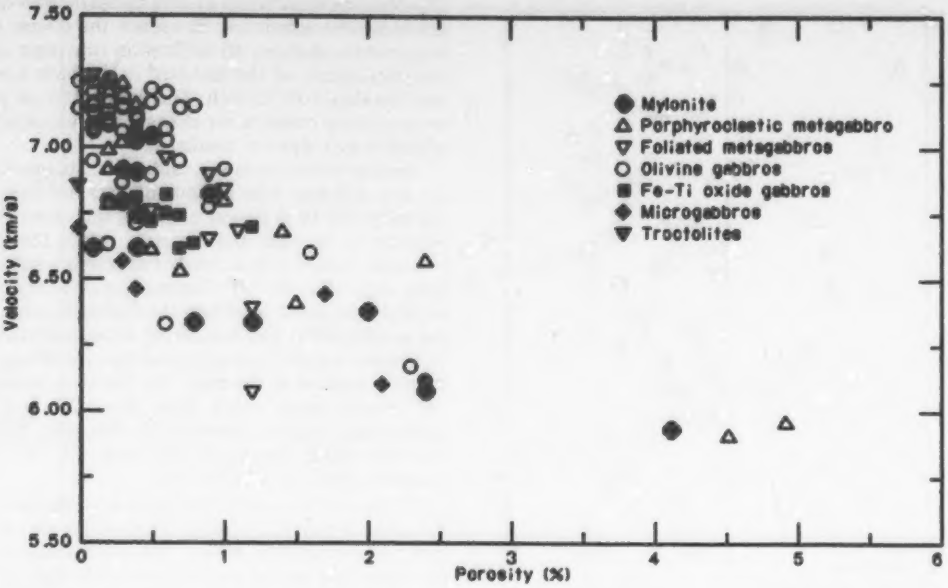

Figure 63. Velocity vs. porosity, using the same rock-type symbols as in Figure 62. Note the systematically lower $V_p$ values for the higher-porosity rocks of a given rock type.

ture of the data may emerge when combined with the lithostratigraphic log to produce velocity and density logs.

The observed $V_p$ anisotropy of oriented cubes cut from the core has interesting implications concerning remote sensing of fault zones in the lower oceanic crust using seismic-reflection techniques. Although the sheared rocks represent a minority (25%) of those recovered from Hole 735B, they might still be detected by modern seismic-refraction techniques. Azimuthal variation in $V_p$ in the oceanic crust may originate from foliation development in the lower crust, rather than that caused by fracturing in the upper crustal basalts (see references in the review by Kirby and Kronenberg, 1987). The marked $V_p$ anisotropy among the mylonitic metagabbros (averaging 8%) might also be detected from reflections of elastic waves at the mylonite-host rock boundaries, which are often very sharply defined. Maximum elastic impedance should obtain for normal-incidence *P* waves. The full elastic wave energy partitioning between incident, reflected, and refracted waves in an anisotropic setting should be investigated from this standpoint.

These results have important implications about the nature of the Moho discontinuity in the deep ocean basins. It has been suggested that the uppermost mantle might be extensively serpentinized. If the rocks recovered from Hole 735B are typical of the lower oceanic crust, then the low $V_p$ of serpentine (6.3 km/s) implies that no more than 30% serpentization might be present for a significant discontinuity (say, 0.4 km/s) to occur between gabbroic rocks of the lower crust and partially serpentinized peridotite of the uppermost mantle.

## THERMAL CONDUCTIVITY

### Introduction

Core samples from Hole 735B were measured nondestructively for thermal conductivity in the shipboard laboratory. Measurements were performed for about 5 to 6 min with a heated needle probe sandwiched between the sample and a slab of low-conducting material (Vacquier, 1985). This method is most convenient for hard-rock cores, which are cut in the form of a half-round cylinder as this shape is easily adapted for the apparatus.

The theory of the method closely approximates the heating of a line source in a plane separating half-spaces of the sample material and a thermal insulator, which in turn is a relatively straightforward extension of the heating of a uniform complete-space method by a line source (Jaeger, 1956; Von Herzen and Maxwell, 1959). If the substrate on which the sample is placed were a perfect thermal insulator, the rise in temperature with time at the needle probe would be exactly twice that experienced by the probe in an infinite medium having the same thermal conductivity as the sample. In practice, the low-conducting substrate absorbs a fraction of the heat during measurement, which depends on the ratio of sample to substrate conductivity. For most of the rock samples measured at this site, this ratio is large enough (>15–20) for the adjustment from the simple theory to require a relatively small correction. This correction is determined by careful measurements using materials of known conductivity that have values near those measured for the samples.

Measuring rock thermal conductivities using this technique was sporadic during previous ODP legs. Measurements for nine basalt samples were reported from Leg 109, Site 648, as well as some from Leg 111, Site 504 (K. Becker, pers. comm., 1987). These studies indicated that the multiplication factors for converting the conductivity value calculated from the full-space theory to the actual value represented by the samples ranged from about 2.1 to 2.7, apparently depending on the time period used after beginning the transient experiment. These factors were obtained by comparing values for standard materials determined over the same time periods in the same apparatus. The following discussion presents some reasons why such unexpectedly large and variable correction factors were determined, and some suggestions for improving the measurements.

### Measuring Techniques

#### *Calibration Standards*

To improve the accuracy of the data obtained, two new calibration standards were used for Leg 118. One is a plate of fused silica glass, about 10.3 cm square by 2.5 cm thick, with uniform and well-established conductivity (1.38 W/m/K; Clark, 1966).

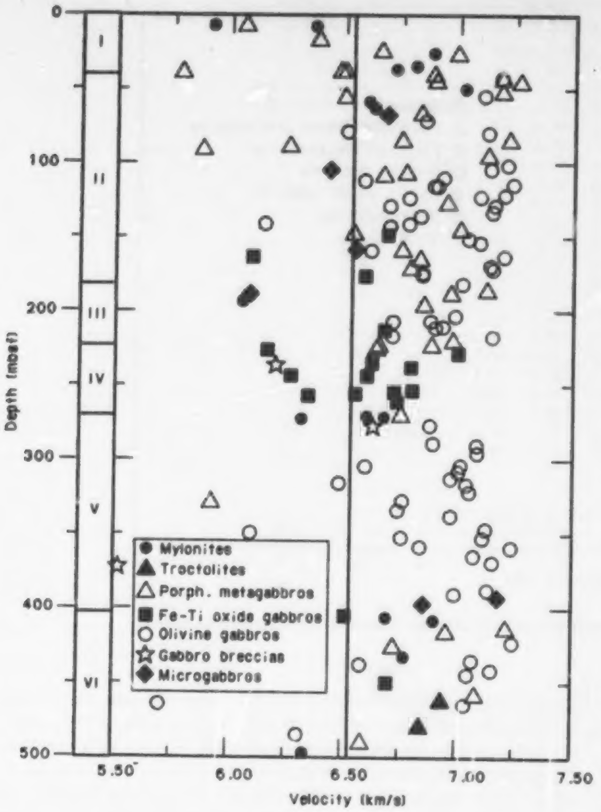

Figure 64. Velocity-depth data for Hole 735B, using the same symbols as in Figure 62. The lower velocities of the shallow rocks reflect their generally higher porosities and locally higher proportion of low-grade alteration minerals. The lower velocities associated with the oxide-rich gabbros at about 250 mbsf are also evident. Also shown lines are the boundaries of the lithologic units described in the "Lithostratigraphy" section (this chapter). The vertical line indicates the average $V_p$ determined from the VSP experiments ("Vertical Seismic Profiling" section, this chapter).

This plate was used in place of the thin (0.6-cm-thick) plate available previously, which gave confusing results during previous legs for any measurements lasting more than 1 to 2 min (see below). The other new standard is a slab of synthetic material designated as "Macor," having a conductivity reported as 1.68 W/m/K by the manufacturer, which is near those values expected for igneous rocks of the oceanic crust. This material was obtained in the form of a short cylinder about 10.3 cm in diameter by 8 cm long, which was cut in half along the axis to give it the same shape (although somewhat larger) as the half-round core sample sections.

### *Calibration Tests*

Before and while measuring the samples obtained from this hole, several measurements were performed using both of the above calibration standards. These measurements were run over a transient needle-probe heating duration of 6 min to determine the best period during which data should be obtained. Almost all the measurements produced the same heating pattern: an initially steep slope of temperature vs. *ln* time over the first 60 to 90 s, gradually decreasing to a more uniform slope, sometimes trailing off to a slightly reduced slope over the last minute (Fig. 65). Most measurements of core samples from this hole showed the same characteristics. To reduce the effects of any external temperature changes, all calibration runs were conducted when the temperature of the standard in the bath was changing at a rate less than 0.01°C/min. The data reduction program will remove a linear temperature change, but inaccuracies occur if the change is too rapid or nonlinear.

Measurements from the calibration standards were analyzed for two different time periods of data acquisition: one during the early (30–66 s) period of rapid, quasilinear change of temperature vs. *ln* time, and the other during the later (60–90 s to 5–6 min) period with a nearly linear relationship (Fig. 66). Results show that the "*F*" factors (i.e., the factors necessary to multiply the result to obtain the standard value, assuming that the needle probe was measuring in an infinite medium of the calibration material) are separated into two groups, depending on the time interval of the data. For the early transient period, the "*F*" factors range widely from about 2.2 to 2.8, significantly greater than expected theoretically (Vacquier, 1985), whereas for the later linear period of the data, the "*F*" factors cluster around a value of 2.0 (Fig. 66).

These results suggest that more accurate and uniform values would be obtained by using the data during the measuring period from about 1 to 6 min. The more scattered results during the early time period with anomalously high "*F*" factors may be explained by several effects. Probably, most important is that the needle probe is not mounted exactly symmetrically between the low-conductivity substrate of the experimental apparatus and the sample (or standard); rather, it is flush with the surface of the substrate, so that the initial heating period will be affected more strongly by its low conductivity, which explains the systematically higher slopes and higher "*F*" factors. The scatter of the early time results may also result from the variability in surface roughness of the sample, or in the amount of grease used to improve thermal contact between the substrate and the sample or calibration standard. For convenience, a relatively low-conducting silicon grease was used; a higher-conductivity grease might alleviate this problem to some extent. However, although use of a higher-conducting grease might reduce some of the scatter in the results, it seems unlikely to eliminate the anomalous systematic differences between the early and late time measurements described above.

Note that the mean "*F*" factor for the silica glass standard is 1.94, whereas for the Macor standard it is 2.01, using the standard values given above. The former is near that expected (1.95) when using the empirical relationship proposed by Vacquier (1985, Eq. 5), whereas a factor of 2.0 could only be approached (not exceeded) for a large sample-to-substrate conductivity ratio. We surmise that the conductivity of the Macor standard is somewhat lower than the value quoted. Assuming that the average "*F*" factor for Macor should be about 1.96 because it has significantly higher conductivity than silica glass, we estimate the conductivity of this standard as 1.64 W/m/K.

## Results

A total of 56 measurements was performed on 38 rock core samples from Hole 735B (Table 11) using the techniques described above. All data were carefully edited to remove the early nonlinear transient heating, and only the linear portions of the temperature vs. *ln* time relationships were used, usually between about 1 and 5 min after initiating the heating. The time period during which data were used varied from a minimum of 30 to 120 s, to a maximum of 4 to 6 min. The variability of this time range between measurements probably indicates differences in the details of placing the sample in the measurement apparatus, with consequent variability in boundary conditions near the

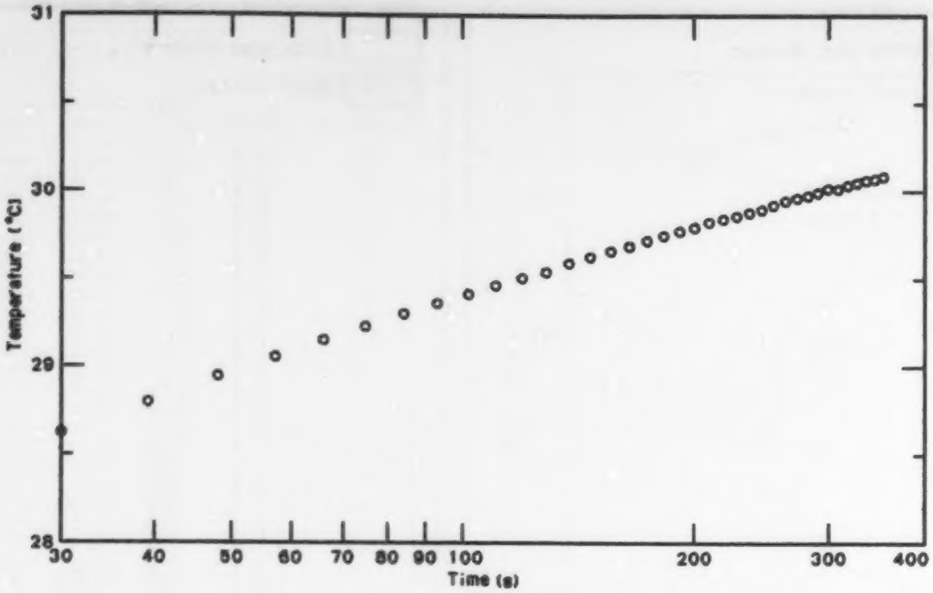

Figure 65. Plot of the data for a typical thermal conductivity measurement of a rock sample using the needle probe and the half-space method. Note that the slope of the temperature vs. *ln* time relationship is steeper over the first few data points and tends to a linear relationship after 60 to 90 s.

needle probe. A constant "*F*" factor of 1.97 was used to multiply the value calculated as if a full-space of the sample were being measured to obtain the actual value, based on tests with calibration standards. This value is slightly larger than that determined with the silica glass standard (see above) to account for the systematically higher conductivity of the rock samples. Consistency of the values and results of repeat measurements show that the values have uncertainties on the order of 5%, although no formal error analysis was conducted.

The variability of values between samples is significantly greater than the experimental uncertainty, which reflects real differences in conductivity. Measurements were repeated for about half of the samples with the needle probe aligned in orthogonal directions, usually parallel or perpendicular to the core axis, to determine any anisotropy. In most cases, foliation in the samples is subhorizontal (see "Petrography" section, this chapter), although the needle probe measures a combination of the conductivity in two orthogonal directions as a result of its radial geometry. Most of the samples showed slightly greater conductivity with the needle aligned parallel to the core axis (Fig. 67), although the differences are generally small, of the order of the experimental uncertainty.

Generally, the thermal conductivity values do not indicate any large variation with depth in the hole, although the mineralogy varies throughout the section and probably accounts for much of the variability observed. There may be significantly higher conductivity between depths of about 100 to 240 mbsf (Fig. 67), although we cannot be sure because of the local variability. The somewhat lower conductivity values between 250 and 300 mbsf may correspond to the iron-titanium oxide-rich gabbros found in this depth interval (see "Primary Petrography" section, this chapter). The mean of all the values determined is 2.21 W/m/K, with a standard deviation of 0.22 W/m/K, which is within the variability of the values for gabbro reported by Clark (1966, Tables 21-4 and 21-5).

## TEMPERATURE MEASUREMENTS

### Introduction

Temperatures were measured in Hole 735B and in the ocean above it with a high-resolution probe provided by the U. S. Geological Survey (USGS). Two runs were conducted that were separated by a time period of 38 hr to obtain data for estimating an equilibrium conductive temperature profile for the borehole (Becker et al., 1983).

#### *Temperature Logging Equipment*

The sensor of the USGS probe is a Sostman platinum wire resistance element (type PT-139X) having the following characteristics.

| | |
|---|---|
| Element length | 1.57 cm |
| Element diameter | 0.26 cm |
| Time constant | 2.3 s |
| Resistance at 0°C | 100.020 ohms |
| Resistance at 100°C | 139.229 ohms |
| Temperature coefficient | 0.00392 ohms/ohm/degree (±0.1% at 0°C) |

The sensing element is attached to the bottom of a weighted, high-pressure probe housing, where it is protected by a metal cage that allows the fluid in the borehole to flow over and around it as the probe is lowered or raised in the hole. The probe is 5.3 m long, 6.35 cm in diameter, and weighs approximately 120 kg in air.

Prior to Leg 118, temperature calibration data for the sensor were obtained from the Yellow Springs Instrument Co., Yellow Springs, Ohio. A third-degree polynomial was fitted to the calibration data in the range 0–200°C, with a standard error of 0.004°C. This equation was incorporated in the computer program used to acquire data.

During logging, the resistance of the sensing element was measured in a four-point, current-potential system by an HP-

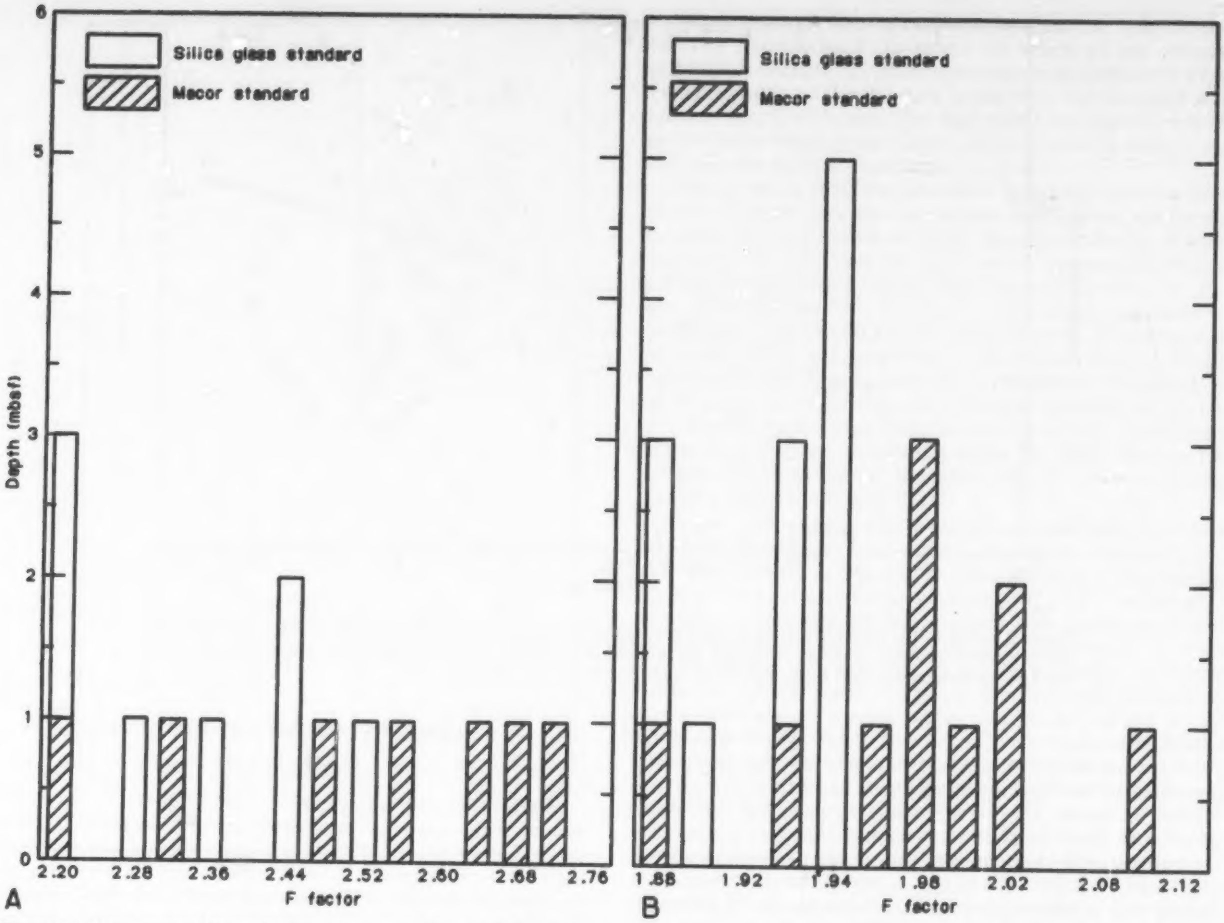

Figure 66. Histograms of the "*F*" factors (see text) calculated for measurements of thermal conductivity standards over different periods of time after the probe first heats. A. Early data (30 to 66 s). B. Late data (1/1.5 to 5/6 min). Note that the horizontal scale divisions for the early data are twice those of the later data. Values for standards assumed as 1.38 W/m/K for silica glass and 1.68 W/m/K for "Macor."

3455A DVM having a readout resolution of 5.5 digits. The digital resistance readings were transferred to the data acquisition computer (HP-9845B) via an HPIB interface cable, where they were converted to temperature by the third-degree calibration equation. The depth of the probe was obtained from the depth register of the ship's wireline winch system, which was read continually by the MassComp computer in the Downhole Measurements Laboratory and sent to the HP-9845B computer via an RS-232 cable link. Depths and temperature readings were recorded on digital magnetic tape by an HP-9875A tape deck. A block diagram of the temperature measurement system is shown in Figure 68.

Pre-logging temperature bath tests (0°–60°C) aboard the *Resolution* indicated that the temperatures measured by the sensor-DVM-computer system were accurate to 0.1°C, and that changes as small as 0.01°C were detectable by the system. When test measurements were conducted using a short cable connecting the probe to the DVM, the system noise was less than 0.01°C. But when measurements were performed through the logging cable, the noise increased to ±0.04°C.

### *Logging Data*

We started the first logging run at 1330 hr on 6 December 1987, recording temperatures every 0.2 m as we lowered the probe through the pipe to the seafloor at a speed of 12 m/min. Because the water inside the pipe had not been disturbed significantly since the navidrill was pulled out of the hole at 2400 hr on 4 December, the temperature inside the pipe was nearly in equilibrium with that of the seawater. The temperature profile in this interval showed a normal decrease from about 20°C at the surface of the ocean to 10° at the seafloor (Fig. 69).

As the probe approached the seafloor and entered Hole 735B at 1442 hr, we reduced the logging speed to 7 m/min and held it constant, recording temperatures every 0.2 m to a depth of 1226 mbrf (494.7 mbsf), which allowed a margin of safety of 6 m to the bottom of the hole at 1232 mbrf (500.7 mbsf). After the probe entered the top of the hole, the temperature increased rapidly from 10°C at the seafloor to nearly 13°C at a depth of 770 mbrf (39 mbsf), and then gradually decreased to about 11°C near the bottom of the hole. The temperature profile recorded for Run 1 is shown in Figure 69, together with the computed temperature gradient. The gradient was computed by subtracting the average temperature in the 10-m interval above the plotting depth from the average temperature in the 10-m interval below this depth and then dividing this difference by the 10-m spacing between the centers of the averaged intervals. Thus, the gradient plotted in Figure 69 is based on a 10-m differential temperature with 10-m boxcar smoothing.

A second temperature log was run in Hole 735B about 38 hr after the first run, using the same equipment, techniques, and

Table 11. Summary of thermal conductivity data, Hole 735B.

| Core/section | Interval (cm) | Depth (mbsf) | Thermal Conductivity (W/m/K) | |
|---|---|---|---|---|
| | | | Parallel[1] | Perpendicular[2] |
| 118-735B-12R-1 | 36–41 | 39.8 | 2.30 | 2.35 |
| 12R-1 | 55–62 | 40.0 | 2.19 | — |
| 14R-1 | 20–26 | 51.4 | 2.20 | — |
| 14R-3 | 122–130 | 55.2 | 2.06 | — |
| 16R-1 | 80–86 | 62.6 | 1.94 | 1.90 |
| 19R-1 | 138–145 | 76.1 | 2.15 | 1.94 |
| 19R-3 | 126–133 | 79.0 | 2.07 | — |
| 23R-3 | 33–41 | 103.8 | 2.82 | 2.57 |
| 25R-3 | 42–49 | 114.0 | 2.11 | 2.27 |
| 27R-3 | 21–29 | 124.8 | 2.32 | 2.46 |
| 28R-2 | 105–113 | 128.1 | 2.51 | 2.41 |
| 33R-1 | 93–100 | 154.5 | 2.48 | 2.37 |
| 37R-1 | 77–83 | 176.8 | 2.29 | 2.27 |
| 42R-2 | 123–130 | 203.8 | 2.32 | 2.07 |
| 44R-1 | 102–110 | 207.1 | 2.48 | 2.34 |
| 47R-1 | 34–41 | 226.4 | 2.27 | 2.16 |
| 49R-1 | 53–61 | 236.6 | 2.34 | 2.01 |
| 51R-1 | 52–60 | 243.6 | 1.96 | 1.71 |
| 53R-2 | 81–86 | 255.3 | 2.21 | 2.07 |
| 55R-2 | 45–55 | 267.0 | 1.78 | 1.82 |
| 56R-2 | 76–85 | 272.3 | 2.16 | 2.16 |
| 57R-3 | 23–30 | 278.3 | 2.01 | — |
| 59R-3 | 126–134 | 289.8 | 2.28 | — |
| 62R-4 | 32–39 | 305.4 | 2.24 | — |
| 64R-1 | 18–24 | 315.2 | 2.29 | — |
| 65R-1 | 34–43 | 320.4 | 2.12 | — |
| 67R-3 | 79–87 | 333.8 | 2.22 | — |
| 71R-2 | 50–57 | 353.0 | 2.30 | — |
| 72R-2 | 90–98 | 358.4 | 2.09 | — |
| 75R-5 | 31–38 | 390.9 | 2.55 | — |
| 76R-6 | 21–28 | 401.7 | 2.29 | — |
| 77R-2 | 37–46 | 405.4 | 2.04 | 1.92 |
| 79R-3 | 127–136 | 418.8 | 2.31 | — |
| 80R-7 | 56–64 | 433.6 | 2.10 | — |
| 81R-3 | 142–150 | 438.0 | 2.34 | — |
| 85R-6 | 134–145 | 480.4 | 2.02 | — |
| 86R-4 | 24–34 | 485.8 | 2.63 | — |
| 87R-3 | 72–78 | 494.2 | 2.30 | — |

[1] Conductivity measured with needle probe parallel to core axis.

[2] Conductivity measured with needle probe perpendicular to core axis.

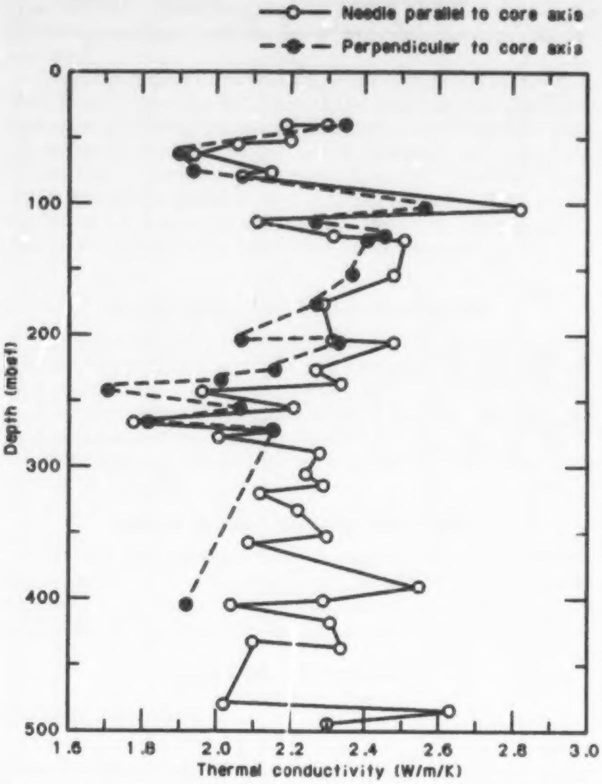

Figure 67. Thermal conductivity vs. depth below seafloor for Hole 735B. Data plotted are those found in Table 11.

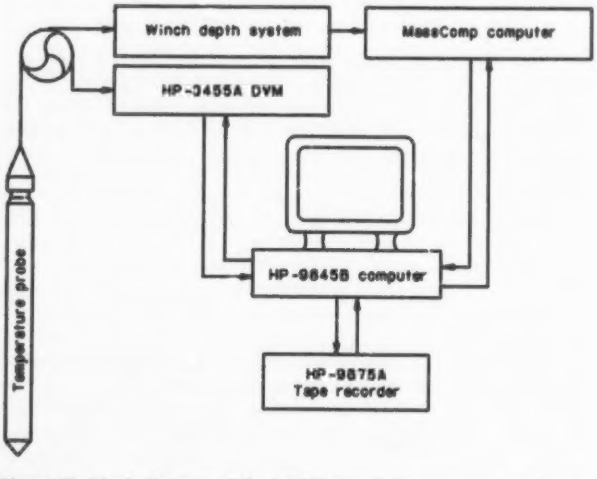

Figure 68. Block diagram of the USGS downhole temperature-measuring system used to log Hole 735B.

logging speeds. The probe entered the hole below the seafloor for Run 2 at 0445 hr on 8 December. Results shown in Figure 70 indicate that most of the hole cooled an average of about 1.5°C during the 38-hr interval between runs, with somewhat greater cooling near the bottom of the hole than at the top. However, the general shape and character of Run 2 closely matches that of Run 1, including two small positive anomalies at depths of approximately 920 mbrf (190 mbsf) and 990 mbrf (260 mbsf). These anomalies may reflect changes in thermal properties or fracturing and hydrology in the vicinity of the mineralized sections of the hole, where concentrations of magnetite and ilmenite occur in the gabbro.

Data from the two temperature runs and the drilling records were used to estimate the equilibrium temperature profile that we expected to find in the borehole when the thermal disturbance from drilling had completely dissipated. The technique, described by Becker et al. (1983), is based on the following equation for calculating the time-decay curve of the temperature disturbance caused by drilling.

$$T = \frac{Q \log}{4\pi K}(1 + t_D/t), \qquad (1)$$

where $Q$ = thermal disturbing source (Bullard, 1947),

$K$ = thermal conductivity of crust,

$t_D$ = time duration of drilling and circulation,

$t$ = time after drilling and circulation ceased until measurement.

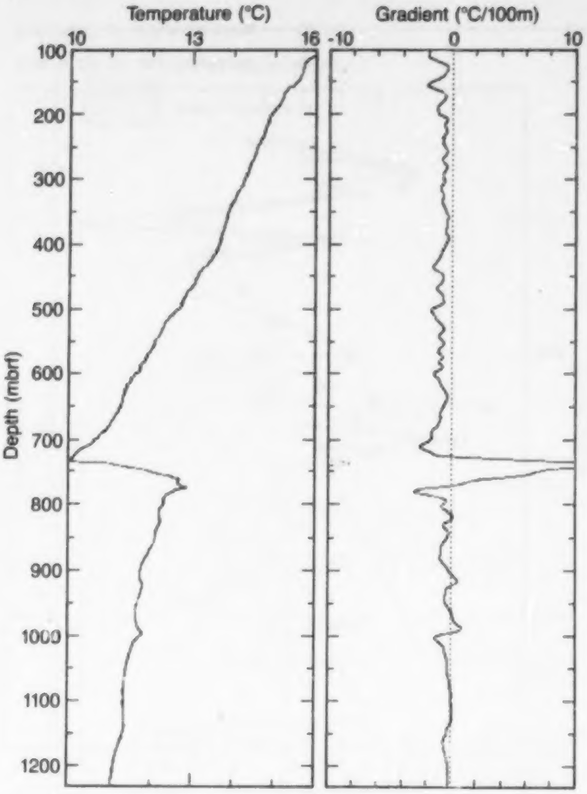

Figure 69. Temperature Run 1, Hole 735B, with observed temperature at 0.2-m vertical intervals and temperature gradient smoothed over 10-m intervals (see text) plotted vs. depth below rig floor (m). Temperature was logged traveling down the hole at 7 m/min. Entry time into the borehole was 1442 hr, 6 December 1987.

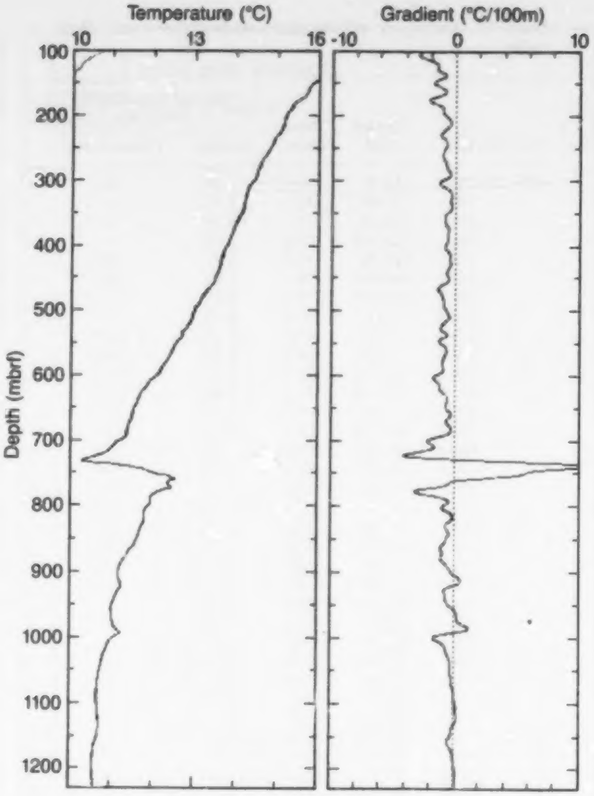

Figure 70. Temperature Run 2, Hole 735B, with the same parameters as for run 1 (Fig. 71), except that entry time into the borehole was 0445 hr, 8 December 1987.

If we replace the temperature disturbance, $T$, in Equation 1 with $T_1(z) - T_e(z)$ for logging Run 1, and $T_2(z) - T_e(z)$ for Run 2, where $T_1(z)$ and $T_2(z)$ are the temperatures measured during the two runs, and $T_e(z)$ is the unknown equilibrium temperature profile of the borehole, we obtain Equations 2 and 3:

$$T_1(z) - T_e(z) = \frac{Q \log}{4\pi K} [1 + t_D(z)/t_1(z)] \quad (2)$$

and

$$T_2(z) - T_e(z) = \frac{Q \log}{4\pi K} [1 + t_D(z)/t_2(z)]. \quad (3)$$

If we then take the ratio of these two equations and solve for $T_e(z)$, the factor $Q/4\pi K$ disappears and we obtain:

$$T_e(z) = \frac{R(z)\ T_2(z) - T_1(z)}{R(z) - 1} \quad (4)$$

where

$$R(z) = \frac{\log [1 + t_D(z)/t_1(z)].}{\log [1 + t_D(z)/t_2(z)]}$$

The equilibrium temperature log computed using Equation 4 is shown in Figure 71. The decrease in temperature with time indicates that the hole was heated during drilling by the circulation of relatively warm water from the surface of the ocean. The negative temperature gradient with depth in the upper part of the hole is unexpected and may reflect advection of seawater through permeable rock. We hope to develop a model that will explain these somewhat unusual observations by incorporating the results of the packer permeability measurements and laboratory measurements of thermal conductivity of core with the temperature data.

## SCHLUMBERGER LOGS

### Introduction

A series of Schlumberger tools were the first well logs run in Hole 735B. Four tool combinations were used, including resistivity, geochemical, sonic, and physical-property measurements.

The borehole was flushed with seawater before logging measurements. Two bit sizes were used for drilling—a 10.5-in. bit to 28.4 mbsf and a 9.875-in. bit to a depth of 500.0 mbsf. Following drilling, borehole conditions were considered ideal for logging, thus the side-wall entry sub was not used. The data presented here were digitized with a 0.152-cm digitization interval.

### Run 1 (Dual Induction-Sonic-Caliper-Natural Gamma)

The first run consisted of a combination of induction resistivity, full waveform sonic, caliper, and gamma-ray logs. An electrical short in the cable head (probably from seawater that entered the head) caused poor quality logs. The full waveform sonic results are discussed in the "Multichannel Sonic Log" section (this chapter). Owing to the low amplitude of the *P*-waves, the Schlumberger software was unable to pick reliable arrival times, and thus no sonic velocity log is available.

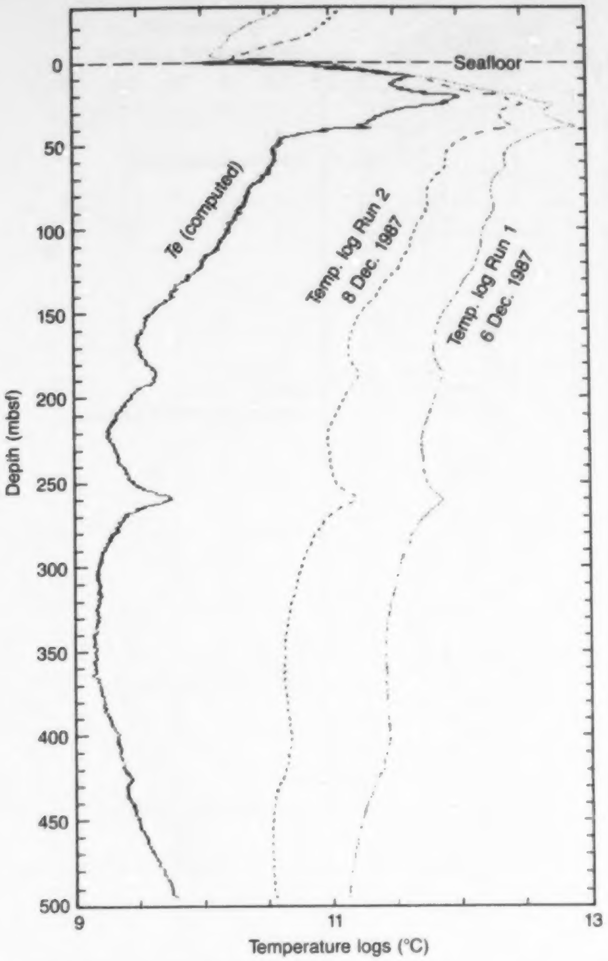

Figure 71. Temperature logging Runs 1 and 2 and calculated borehole temperature equilibrium profile ($T_e$).

### Run 2 (Litho-Density)

The second tool string lowered into Hole 735B was the litho-density probe. The output logs include natural gamma, epithermal and thermal neutron porosity, density, and photoelectric factor. A tool module that provided a three-component magnetometer used to measure borehole azimuth, deviation, and temperature logs was also included in this run. No logging problems were encountered, and all data are of good quality. The logs are presented in Figures 72, 73, and 74.

### Run 3 (Geochemical Combination)

The third run consisted of a combination of tools which together measure the concentration of the elements hydrogen, chlorine, silicon, calcium, iron, sulfur, aluminum, potassium, uranium, and thorium. The tool determines elemental concentrations by measuring both the natural and excitation gamma-ray emisson spectra from the rock. (Refer to the ODP Wireline Logging Manual, 1987, or Serra, 1985.)

Two complete passes of the geochemical tool were recorded to improve its statistical measurements. Results from Run 1 are presented in Figures 75, 76, and 77. The results of both runs were good, but a few minor problems occurred in the data. First, the tool voltage decreased for a short period of time in the first run, causing a small section of poor data between 161 and 165 mbsf.

The second, and unavoidable, problem occurred in the data from Run 2. After the first pass of the tool, the rock was bombarded by a californium source and high-energy neutrons from the minitron tube. The effects of this excitation dominated the second pass measurement of natural spectral radiation, from which potassium, uranium, and thorium are determined. Thus, the elemental concentrations of the preceding three elements should be ignored in the data from the second run.

### Run 4 (Induction Resistivity-Caliper)

The failure of the cable head during Run 1 required a second pass of the induction resistivity and caliper tools. No problems were encountered during this second pass. The output of the tool includes resistivity measurements at shallow, medium, and deep penetration into the rock (ILM, ILD; Fig. 78) and that of borehole diameter (in inches) from the three-arm caliper tool (CALI, in Fig. 72).

### Run 5 (Dual Laterolog Resistivity)

The final Schlumberger run was logged with the dual laterolog resistivity tool. The results include two log curves, corresponding to various depths of penetration (LLS, shallow, and LLD, deep). The laterolog data are presented in Figure 78.

## Log Data Observations

*Borehole Conditions*

The caliper log (Fig. 72) from Hole 735B clearly indicates the change in bit size at 28 mbsf. The log also indicates that the borehole varies up to 1.6 in. in diameter below the level of the bit change. There is a minor correlation of lithology with borehole size, with massive zones showing less variation in diameter. Further discussion of the borehole shape is provided in the "Borehole Televiewer" section (this chapter). The Schlumberger logs have been suitably corrected for changes [illegible] borehole size.

The borehole at Hole 735B is not vertical, as indicated from the deviation log (Fig. 72). The average tilt of [illegible] hole is 5.9° from vertical; it becomes more vertical with depth. The azimuth from this deviation (Fig. 72) varies predominantly between 0° and 40°.

The temperature in the borehole was also determined during the Schlumberger geochemical run; the bottom-hole temperature was 11.7°C (Fig. 73). Further analyses of the temperature profile are presented in the "Temperature Measurements" section (this chapter). The Schlumberger temperature profile is similar to the USGS temperature results.

The three components of the Schlumberger magnetometer, results of which correlate well with the USGS results, also are presented in Figure 73. This tool is not oriented in azimuth, as is the USGS tool. Comparison of the USGS results discussed in the "Magnetometer Logs" section (this chapter) with the Schlumberger logs indicates a high degree of similarity in the data obtained with both tools.

### Physical-Properties Measurements

The thermal and epithermal neutron porosity logs measure the concentration of hydrogen in the rock (Fig. 74). In sedimentary environments, the thermal neutron porosity log is used to determine total hydrogen concentration, whereas the difference between the neutron logs is interpreted as bound water. This interpretation model may not stand up at Hole 735B because the distribution of water does not fit the clay-filled matrix porosity model.

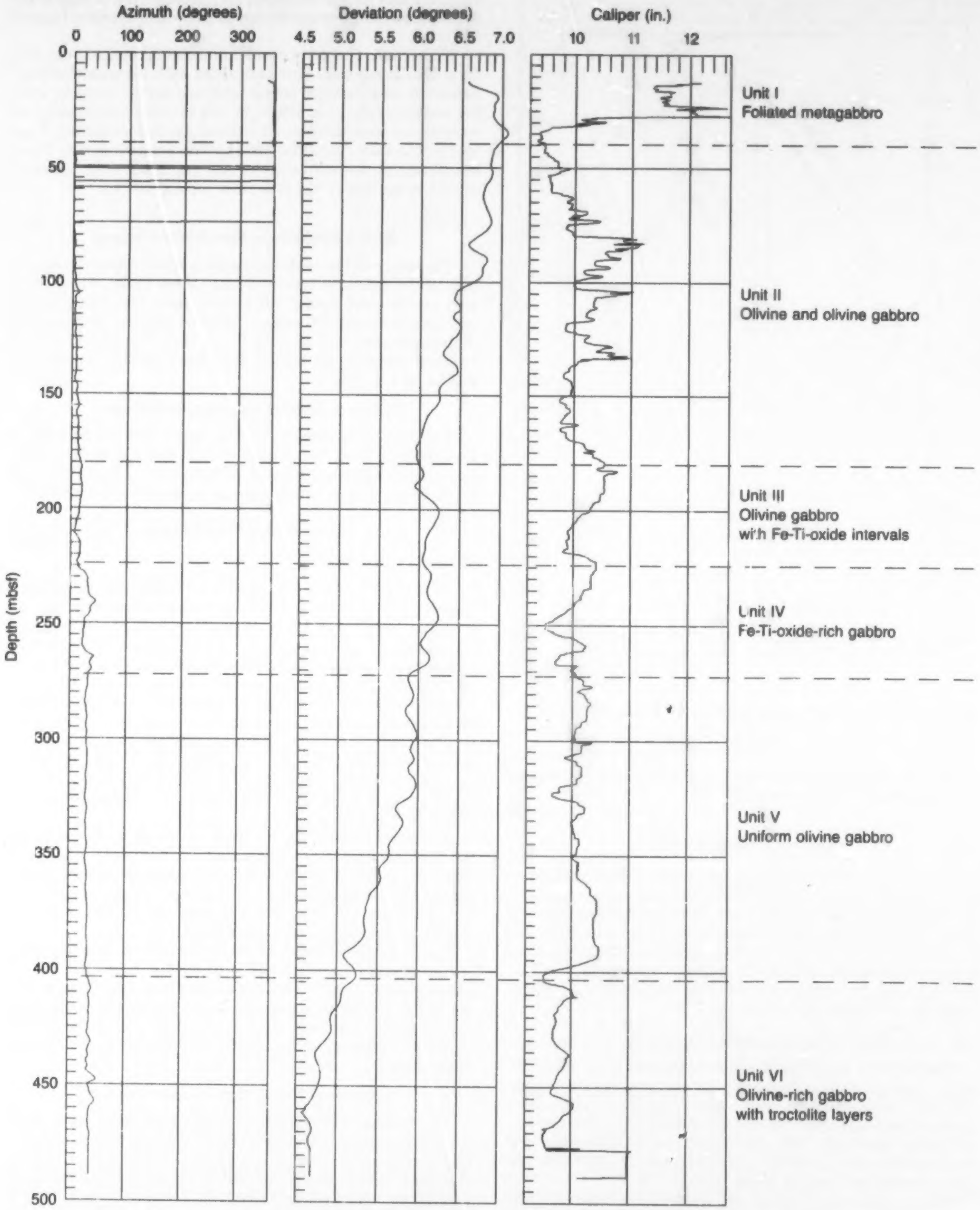

Figure 72. Azimuth, deviation, and caliper logs, with lithologic intervals (see "Lithostratigraphy" section, this chapter).

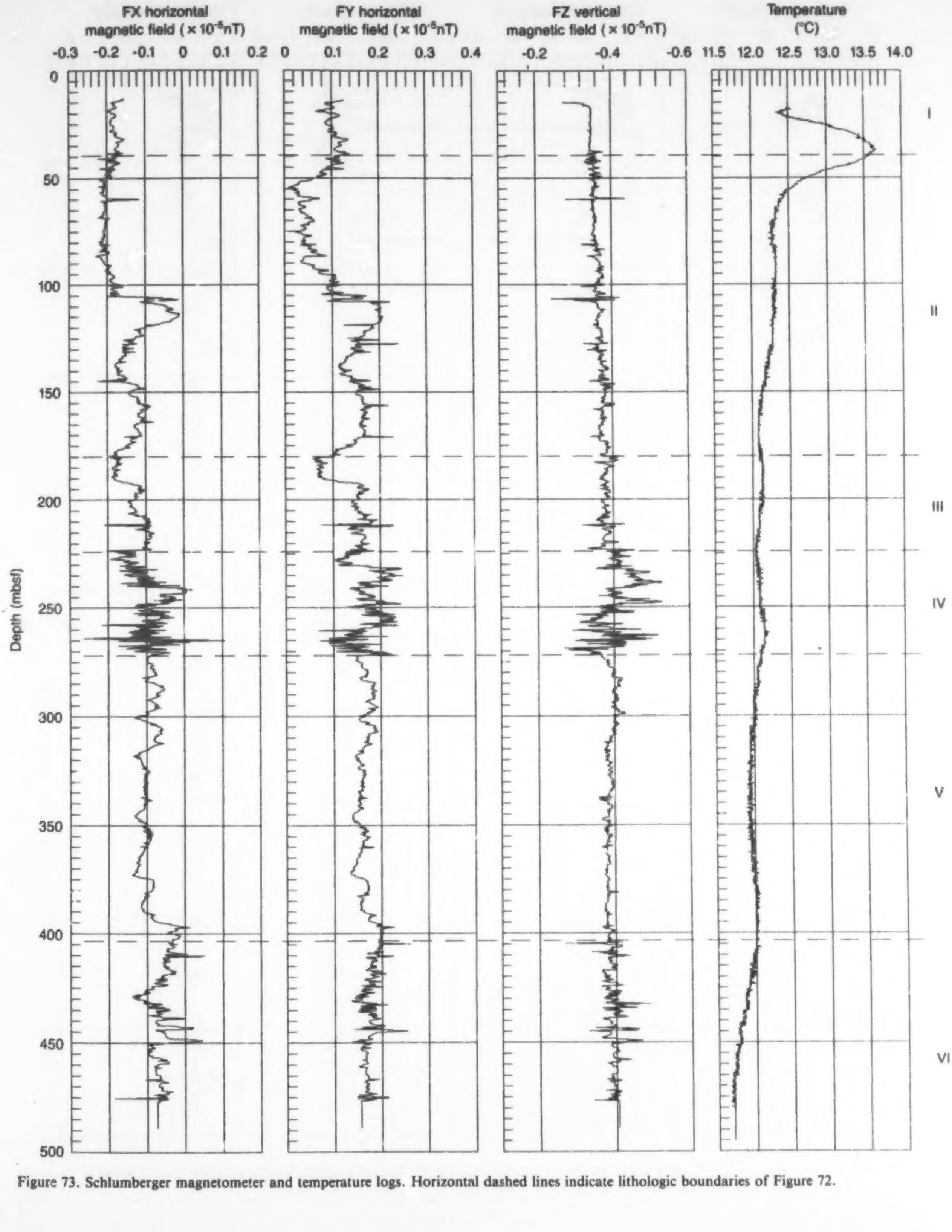

Figure 73. Schlumberger magnetometer and temperature logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

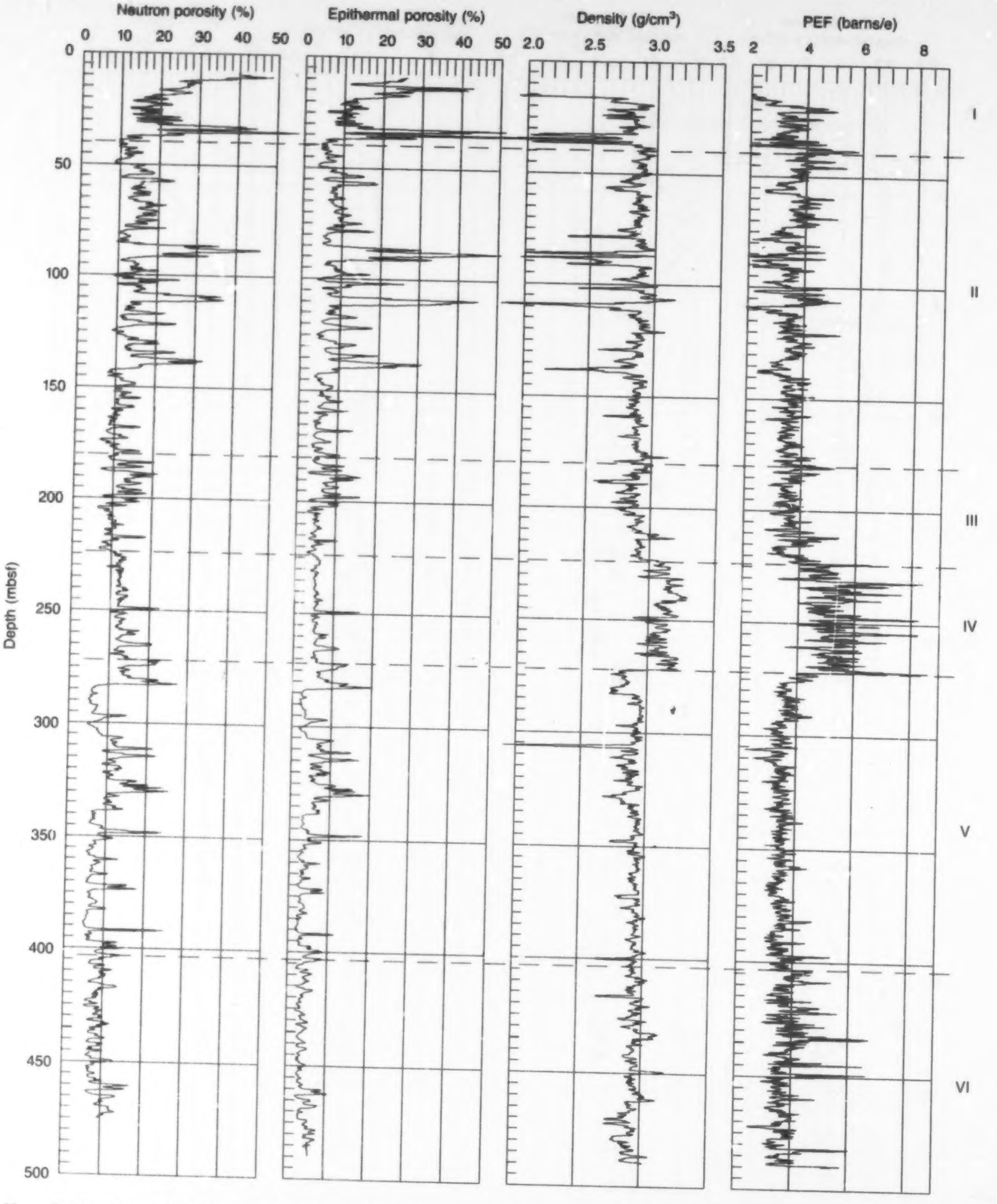

Figure 74. Porosity and density logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72. PEF = Photoelectric factor.

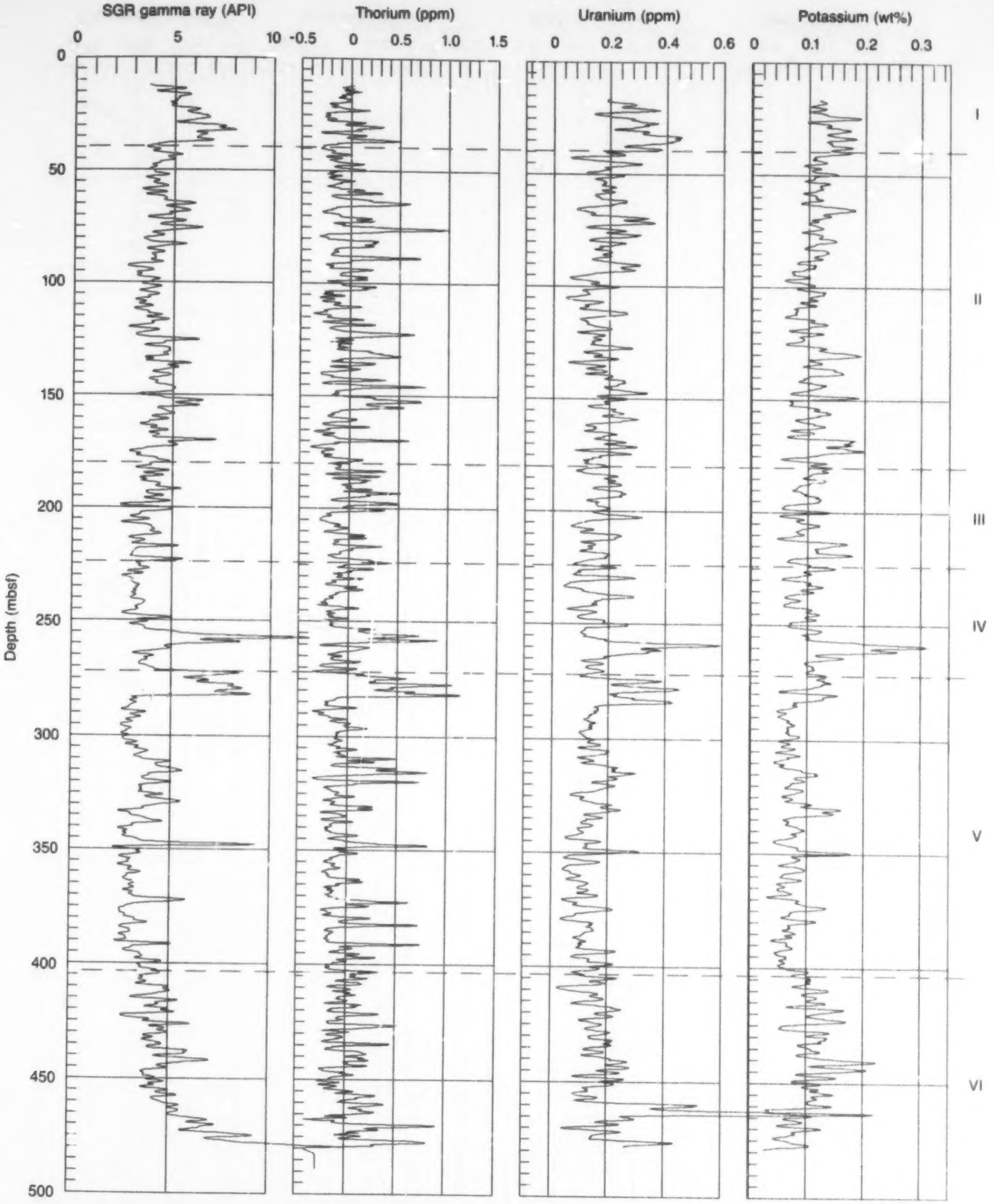

Figure 75. Natural gamma radiation logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

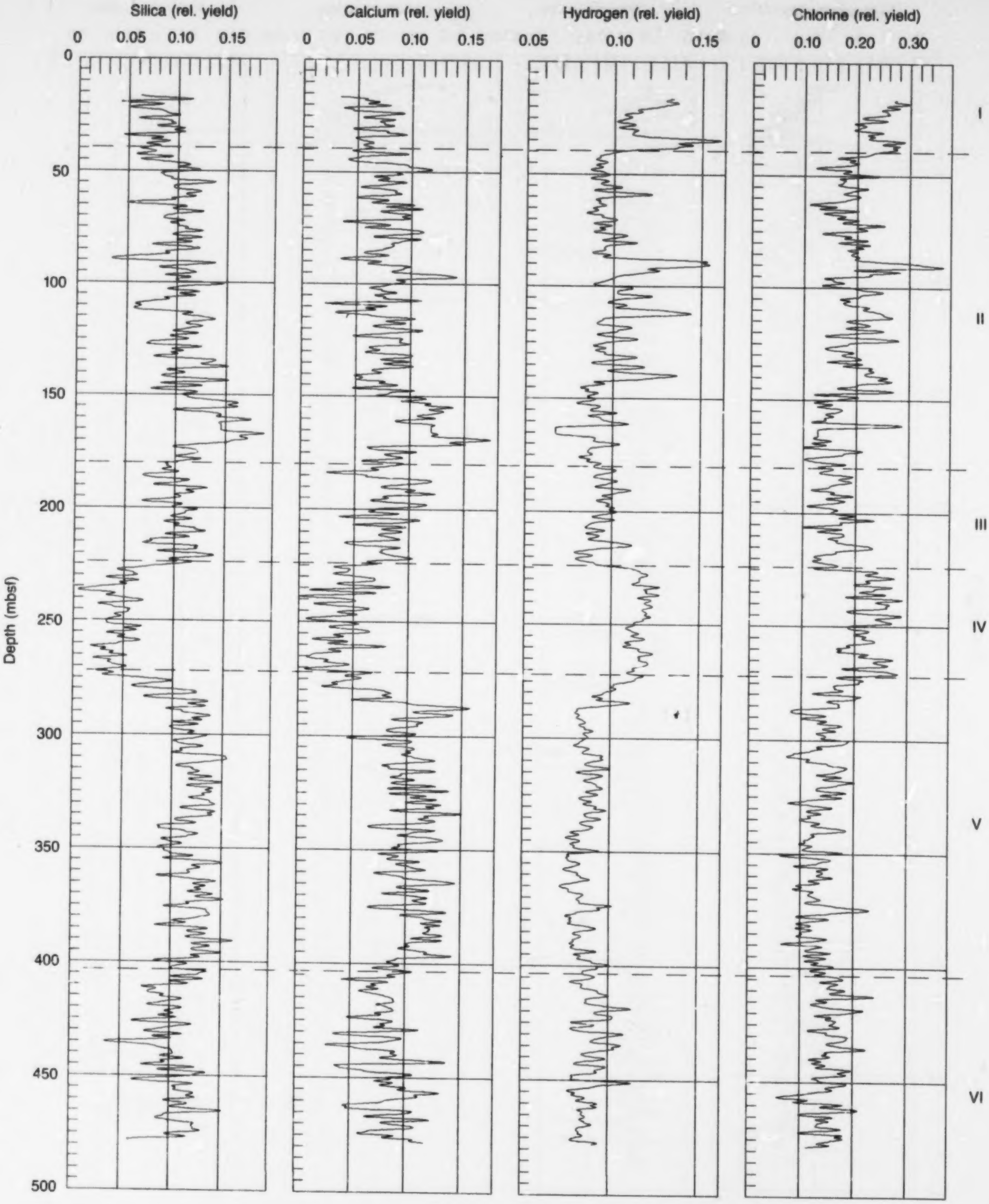

Figure 76. Silica, calcium, hydrogen, and chloride geochemical logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

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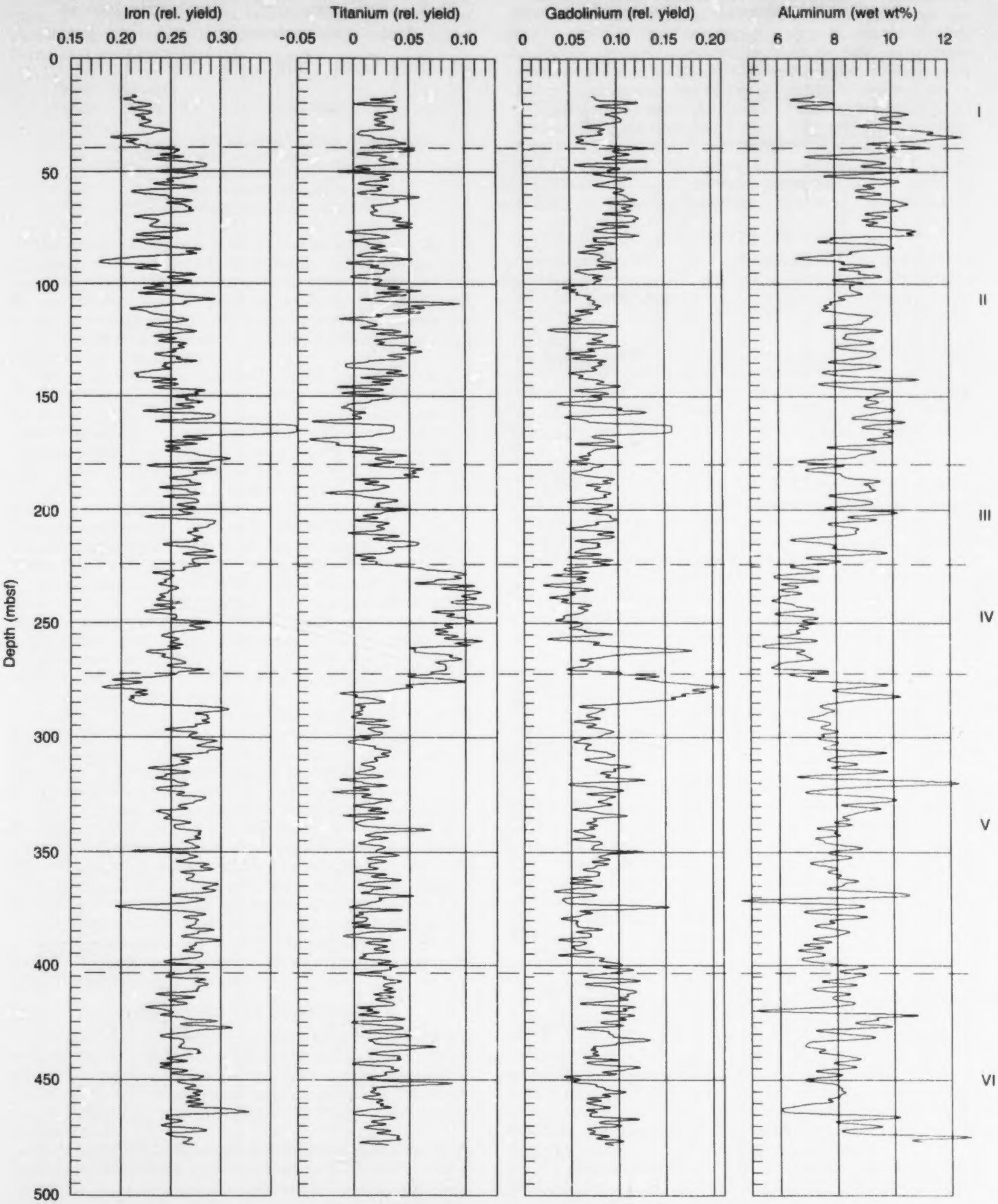

Figure 77. Iron, titanium, gadolinium, and aluminum geochemical logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

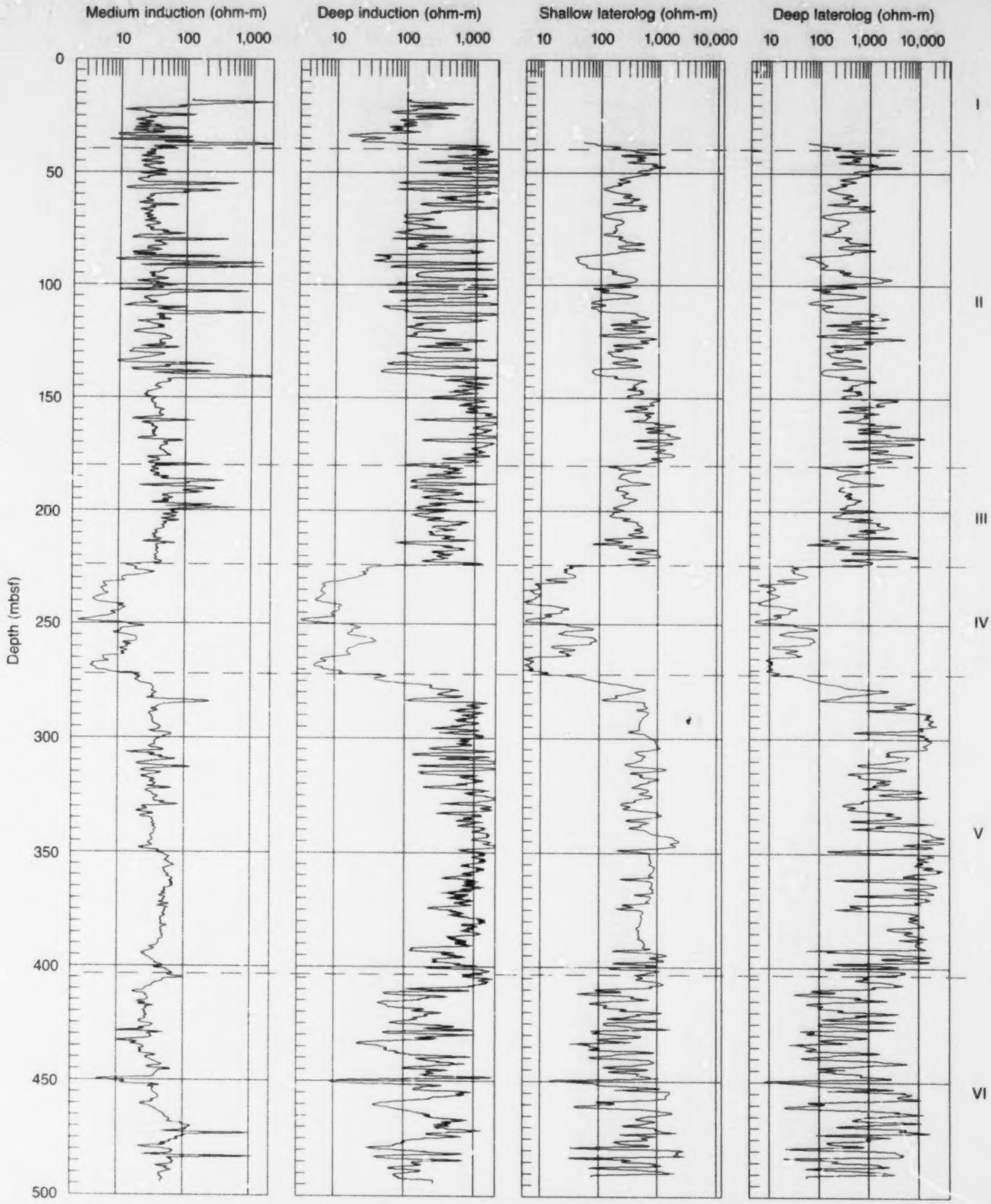

Figure 78. Resistivity logs. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

The neutron porosity varies between 0% and 55% in Hole 735B. The high porosity zones correlate with low-density and high-hydrogen concentration zones from the geochemical log. Zones of interest include:

| Depth (mbsf) | Porosity (%) | Lithology |
|---|---|---|
| 32 | 55 | Massive altered gabbro/missing core |
| 88 | 52 | Mylonitized gabbro |
| 110 | 45 | Amphibolitized metagabbro |
| 139 | 32 | Amphibolitized metagabbro |
| 279 | 20 | Highly altered olivine gabbro |

The epithermal neutron porosity was measured at a low energy level, at which the effects of matrix-bound oxygen (i.e., water) were not measured. Owing to the lower energy level, the log measurement statistics produced a slightly smoother curve, as was observed. At Hole 735B, the epithermal porosity was lower than the log measurement statistics, which does not necessarily indicate bound water.

The density log from Hole 735B provided a continuous profile of bulk density in the borehole (Fig. 74). The tool averages the density of the rock over an approximately 30-cm spherical interval. The density log clearly indicates the same zones of alteration that are evident in the neutron log. In addition, Unit IV shows a significantly higher density than any other lithologic unit in the hole. Low density values may correspond to high porosity zones, where fractures intersect the borehole. Preliminary borehole results show fracturing at 288, 292.5, and 302.5 mbsf. The low density zone at 306 mbsf may correspond to a fracture observed in the borehole televiewer near that depth.

The photoelectric factor (PEF) was measured along with the density (Fig. 74). The PEF measures low-energy gamma-ray absorption. Laboratory measurements of the photoelectric absorption index (Pe) of various elements and minerals have been compiled (see Tables 2 through 4 in *ODP Wireline Logging Manual*, 1987). The log measurement represents the total absorption index of the formation.

At Hole 735B, the rise in the PEF within Unit IV corresponds with the increase in iron and titanium concentrations. For comparison, note that the Pe of magnetite is 22.08, that of illmenite is 16.63, and hematite is 21.48, while the Pe of quartz is 1.806 and that of salt water is 0.807 barns/electron.

Also of interest are the potential effects of uranium and thorium (Fig. 75) on the PEF log. The laboratory-measured Pe of uranium is 2948.74 and that of thorium is 2724.4 barns/electron. We observed that the highly altered zone just below the Unit IV/Unit V boundary, which has a high concentration of thorium and uranium, does not appear as an increase in PEF. We concluded that although the concentrations of thorium and uranium are relatively high in the alteration zone, the effect on the PEF log may be balanced by the reduced concentration of various other high-PEF minerals.

### Resistivity Measurements

The results of the laterolog (curves LLS and LLD) and induction resistivity tools (curves ILM and ILD) are presented in Figure 78 and have been smoothed with a 5-point (0.760-m) boxcar filter. The limitations of each tool must be considered during analysis; the operational limits of the tools were reached in Hole 735B.

The saltwater in the borehole and the initial pore fluid have a low resistivity compared to the rock matrix. Thus, an increase in fracture or connected intergranular porosity results in a decrease in measured resistivity. The matrix resistivity is controlled by rock composition, particularly iron oxides. An increase in iron oxide concentration will significantly reduce the measured resistivity.

Resistivity tools measure the bulk resistivity of the rock and fluid within various size zones of investigation, which are specific to each tool. For this reason, their results are controlled by the relative amount of conductive borehole fluid and resistive rock matrix within the zone. Tools with deeper zones of penetration are influenced less by the conductive borehole fluid.

The method by which the laterolog measures resistivity is significantly different from that of the induction log (Serra, 1985). The laterolog is inaccurate for that range in which the induction log is more accurate. The induction log measurement should be used when the resistivity decreases below 100 ohm-m, while the laterolog should be used when the resistivity is above this value.

### Induction Logs

The medium induction log (ILM) measures the resistivity within approximately 0.5 m of the borehole. Induction logs are designed to give accurate measurements of resistivities below 100 ohm-m. At Hole 735B this occurs only in the iron-titanium oxide-rich zone.

The deep induction log (ILD) has a greater depth of investigation than the ILM and reaches approximately 5 m. Owing to the greater penetration, the log provides a more accurate measure of rock resistivity because it is influenced less by borehole fluid. However, this log is accurate only below 100 ohm-m.

### Laterologs

The deep laterolog (LLD) has a depth of investigation of greater than 1.0 m and provides the closest measure of the true resistivity of the rock for zones where resistivity is greater than 100 ohm-m. However, this log does not have the vertical resolution of the shallow laterolog (LLS). The response of the LLD spans four orders of magnitude, between 4 and 40,000 ohm-m. The variation in the resistivity may be attributed to different factors at different locations in the borehole. The low resistivity zones in Unit II are probably caused by changes in porosity, as confirmed by the neutron and density logs at 87, 108, and 138 mbsf. Lithologic Units III and IV also show reductions in resistivity, which are attributed to increased iron oxide concentrations. The LLD log was saturated at about 4000 ohm-m owing to a malfunctioning electrode. For this reason, the difference in resistivity between the LLS and LLD curves at high resistivity is exaggerated.

The spherically focused resistivity log (SFLU) was run in Hole 735B, although results are of little value and are not shown. The tool has a very shallow depth of investigation and thus is influenced greatly by the contrast between the matrix and borehole fluid resistivity. The oscillations in log response, which occur in the high-resistivity zones, indicate that the tool was operating beyond its measurement limit. The tool was designed to provide a resistivity measure over a 15-cm vertical interval.

### Geochemical Measurements

The geochemical measurements of natural gamma, potassium, thorium, uranium, silicon, calcium, hydrogen, iron, titanium, gadolinium, and aluminum are presented in Figures 75, 76, and 77. These measurements have been smoothed with a 7-point (1.064 m) boxcar filter. The raw data (relative yield) are presented in these figures, and further processing should allow us to calculate the weight percent of these elements and oxides. Note that the geochemical data between 161 and 165 mbsf are poor because of temporary operational problems.

The gamma-ray log or Standard Gamma Ray (SGR) measures the total natural gamma radiation emitted by the rock into the borehole. The log is recorded in API units, the standardized units of the American Petroleum Institute. The most significant characteristic of the gamma log from Hole 735B is the very low API values. For comparison, 10–30 API is typical for a sandstone, whereas 80–140 API is typical of shales. Three significant zones of higher gamma radiation occur in the borehole. The first, at 258 mbsf, corresponds to the trondjhemite layer in lithologic Unit IV. The second zone occurs immediately below the lower boundary of Unit IV and corresponds to a zone of high alteration. The third increase in natural gamma radiation below 465 mbsf is unexplained and conflicts with the natural gamma-ray spectral logs.

While the SGR log measures total gamma radiation, the thorium, uranium, and potassium measurements provide concentration of the three most common sources of gamma radiation. The peak in the SGR log at 258 mbsf corresponds to the only significant peak in the potassium log, which indicates that potassium is more concentrated in the trondjhemite layer. This is confirmed by the XRF measurements.

Comparison of the shape of the thorium and uranium logs with the gamma-ray log indicates that these elements are the primary source of radiation in the borehole at various depths. This is particulary evident in the alteration zone below Unit IV.

The silica, calcium, and aluminum logs show a distinct decease in relative yield in Units III and IV, as observed in the XRF data. The hydrogen and chlorine logs exhibit a shape similar to the neutron log, which allows identification of high-porosity zones. The gadolinium log shows a significant increase in response within the trondjhemite interval at 258 mbsf, and within the alteration zone immediately below Unit IV. The relative yield of iron does not show the expected increase in response within the iron-titanium oxide-rich zone; further investigation will be necessary.

Figure 79 allows us to compare geochemical log results with XRF analyses performed on board the ship. Within the iron-titanium oxide-rich unit, the thin silicon-rich trondjhemite zone appears as a slight increase in silicon concentration. However, the geochemical tool does not have the vertical resolution to detect true concentrations in the zone (for a discussion of the factors affecting tool response, refer to Serra, 1985). Comparison of the titanium measurements indicates a close correlation of log results with laboratory data. Depth offset between peaks in the laboratory and log results (e.g., at 100 mbsf) may be caused by sample offset from vertical shifting of core where recovery was poor.

### Conclusions

The logging results at Hole 735B clearly delineate the iron-titanium oxide-rich gabbros encountered between 223 and 272 mbsf. The resistivity logs responded dramatically to the increased oxides in this zone owing to their electrical conductivity (Clark, 1966). Also evident was an increase in density, along with a distinct reduction in silicon concentrations. A felsic trondjhemite interval within the oxide layer is evident from the small increase in silicon and the significant increase in potassium concentration.

Immediately below the iron-titanium oxide-rich gabbro lies a 12-m-thick zone, where increased alteration is evident. Logs show an increase in silicon, thorium, and neutron porosity, along with reduced density and iron concentration.

In general, the lower section of the borehole is marked by uniform log signatures. The laterolog resistivity, however, shows many intervals of reduced resistivity that may possibly correlate with zones of alteration or increased oxide concentration.

## MULTICHANNEL SONIC LOGS

### Introduction

Sonic logs are run routinely in ODP wells using a two-source, two-receiver Schlumberger (LSS) sonic tool. The Lamont-Doherty multichannel sonic (MCS) tool was used during ODP Legs 102, 109, and 111 to investigate basaltic basement. This tool is a multireceiver signal-source logging device that records 12 sonic waveforms at each source depth. At Site 735, both LSS and MCS tools were run into gabbroic basement to investigate elastic properties and fracturing.

Sonic waveforms may be analyzed to yield compressional, shear, and Stoneley velocities across a receiver span using a semblance correlation to measure the coherence of energy between receivers. The semblance value may also be used to estimate the energy loss across the receiver array. Amplitude thresholds typically are used to provide accurate measurements of compressional and sometimes shear velocity. The low signal/noise ratio of the compressional wave in this gabbro precluded our selecting amplitudes directly and required the use of semblance processing. Generally, in fast formations such as gabbro, dense receiver spacings and long source offsets enable greater precision and higher semblance when computing velocities (i.e., MCS tool). Sonic data are commonly used to determine lithology and to estimate porosity from compressional velocities, fracture location, and structural analysis from semblance values, as well as to estimate pore aspect ratios from calculated $V_p/V_s$ ratios (O'Connell and Budiansky, 1974; Paillet and White, 1982; Kimball and Marzetta, 1984; Goldberg and Gant, 1988).

### Description of Tools

The MCS tool is configured with the source above the receiver string and is separated by a variable-length spacer assembly (Fig. 80). The MCS receiver geometry is similar to that of a surface refraction survey rotated 90°, with 12 receivers spaced 15 cm apart over a 1.65-m linear receiver array aligned along the hole. The LSS tool is configured with two transducers 0.61 m apart and two receivers also 0.61 m apart that are located 2.44 m above the upper transducer. During logging, both tools are centered in the borehole by means of bowspring centralizers. The energy that arrives at each receiver travels as a compressional pulse from the source in the borehole fluid, is refracted at the borehole wall, and then is refracted back into the borehole fluid. Additional guided-wave modes also are produced in the borehole environment, and their propagation is controlled by the properties of both the formation and the fluid-filled borehole. One such mode, the Stoneley (or tube) wave, propagates as a surface mode slightly slower that the fluid velocity. The propagation of waves in a borehole was discussed completely by Paillet and White (1982). The spectral signature of the MCS source was recorded at 80 cm horizontal offset in a water bath at Lamont-Doherty Geological Observatory. Figure 81 shows that the peak power in the spectrum occurs at 22 kHz. The peak is centered on a broad shoulder about 8–10 dB below the peak between 10 and 27 kHz and is at least 6 dB down outside the 18 to 26 kHz frequency band.

Computer control of the tool during logging allowed us to select the depth increment between recorded suites as well as the number of receivers to be used. The data are transmitted uphole in analog format and digitized and recorded on magnetic tape during the logging run. The MCS logging rate depends on the depth increment and the number of receivers per source depth. For the 0.3-m depth increment and the 12 receivers per source depth used in the MCS survey, the logging rate required for the MassComp acquisition software was about 3 m/min. The logging rate was about 10 m/min for the LSS tool.

### Operations

On 6 December 1987, Schlumberger LSS waveforms were recorded during the first logging run in Hole 735B. High-quality waveforms were recorded at a sampling rate of 5 μs for 2.5 ms over most of the interval. However, due to an electrical short in the cable head, two intervals in the hole were missed: 140–160 and 380–450 mbsf. The low signal/noise ratio of the compres-

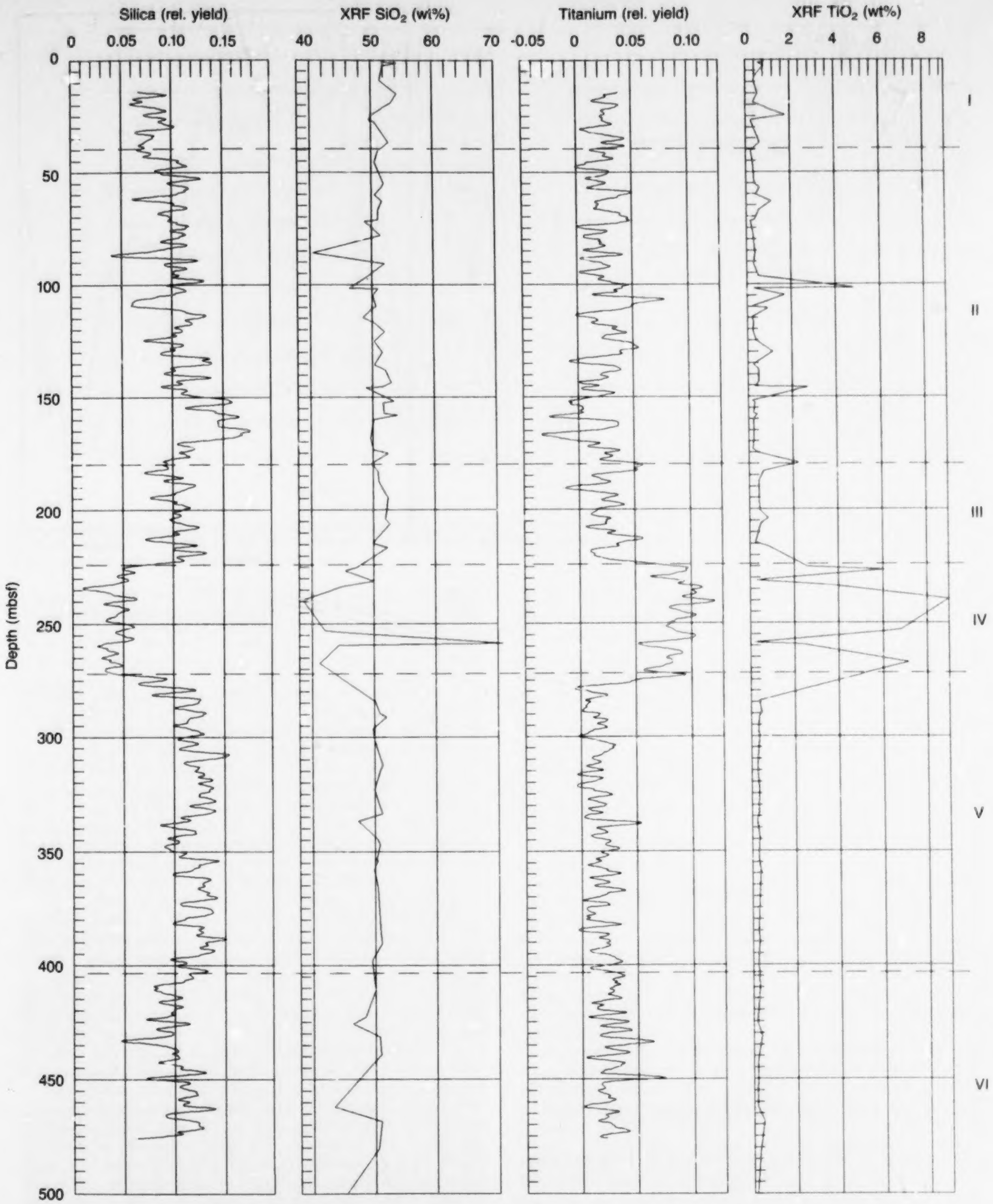

Figure 79. Comparison of geochemical logs with XRF analyses. Horizontal dashed lines indicate lithologic boundaries of Figure 72.

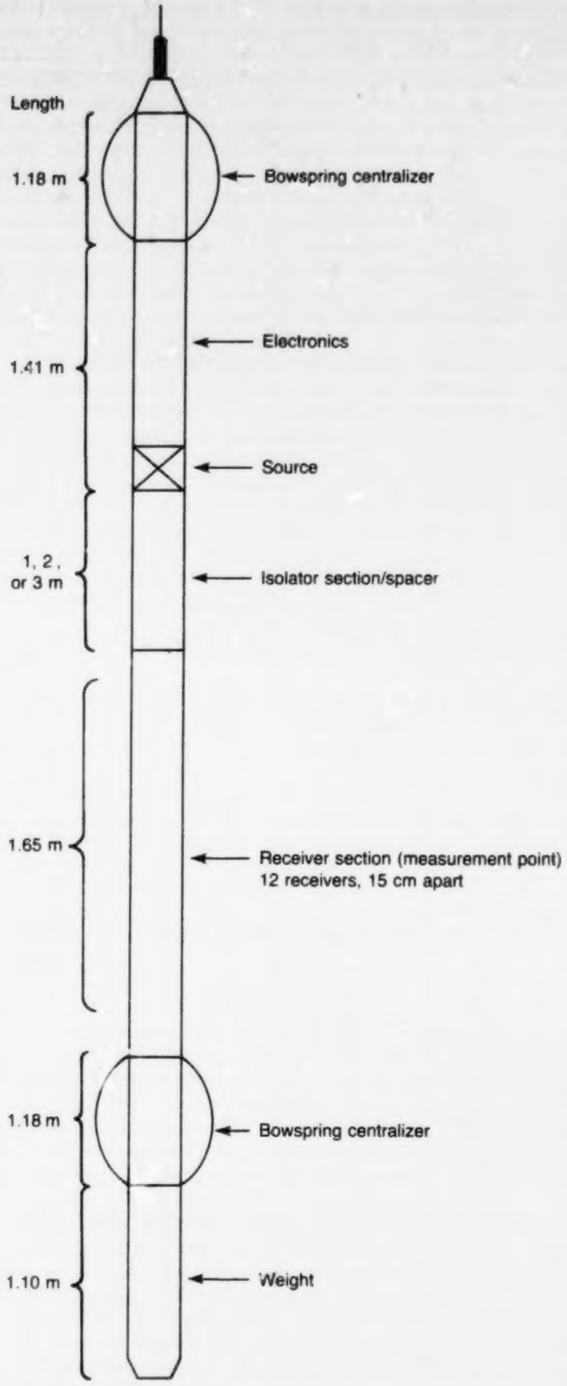

Figure 80. Schematic diagram of the MCS logging sonde.

sional wave in this formation required that the recorded waveforms be processed using a modified semblance calculation for this tool geometry after the log was completed.

On 7 December, MCS data were recorded in Hole 735B from a depth of 484.6 to 13.0 mbsf using a tool configuration that resulted in a separation of 3.81 m between the source and the receiver array. Digital waveforms were recorded for successive source locations at 0.3-m intervals. The waveforms were digitized at a sampling rate of 5 μs for 5 ms. At 125.9 mbsf, one of two spacers between the source and the receiver array shorted by flooding at a failed epoxy joint, and the log had to be aborted. The upper 100.0 m of Hole 735B was logged on 8 December using one spacer at a reduced source-receiver separation of 3 m. In addition, the computer interface that controls the source firing was not operating correctly, and the upper 100 m interval had to be logged using unsynchronized source firing. Data throughout the open-hole interval of the well are good; however, data from the upper 100 m had to be reordered by sequential receiver number before receiver amplitude analysis could proceed.

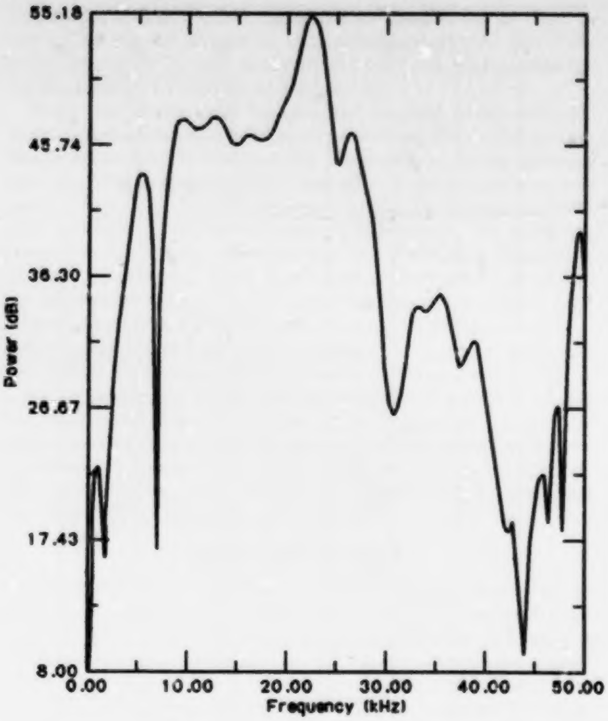

Figure 81. Spectral signature of the MCS sonic source recorded at LDGO in a water bath with an 80-cm horizontal offset. Peak power occurs at 22 kHz and is at least 6 dB down outside the 18 to 26 kHz frequency band.

Single-receiver MCS waveforms at 4.57 m source offset are shown in a variable-density format over a 4-ms recording interval for the entire hole in Plate 1. Depths shown in this plate are meters below rig floor. The data are unprocessed, with the exception of the upper 100 m interval that was reordered after asynchronous recording, based on a pick of the high-amplitude and stable fluid arrival (see Fig. 82). The amplitude of the waveforms (blackness) changes in certain depth intervals and over time. In particular, the upper 100-m interval is more chaotic and has lower amplitudes (it is also plotted at a 5 × scale). This results partly from receiver gain changes from recording without computer synchronization and partly from physical-property changes in the formation. The lower amplitude of compressional waves in this interval can also be seen in the LSS waveform log. The relative amplitudes of compressional, shear, and Stoneley wave modes observed qualitatively in Plate 1 are quantified by the subsequent semblance calculation.

A sample suite of 12 MCS waveforms recorded at 126.0 mbsf with reduced spacing (3 m source-receiver offset) is shown in Figure 82A. Compressional and shear wavemodes are suffi-

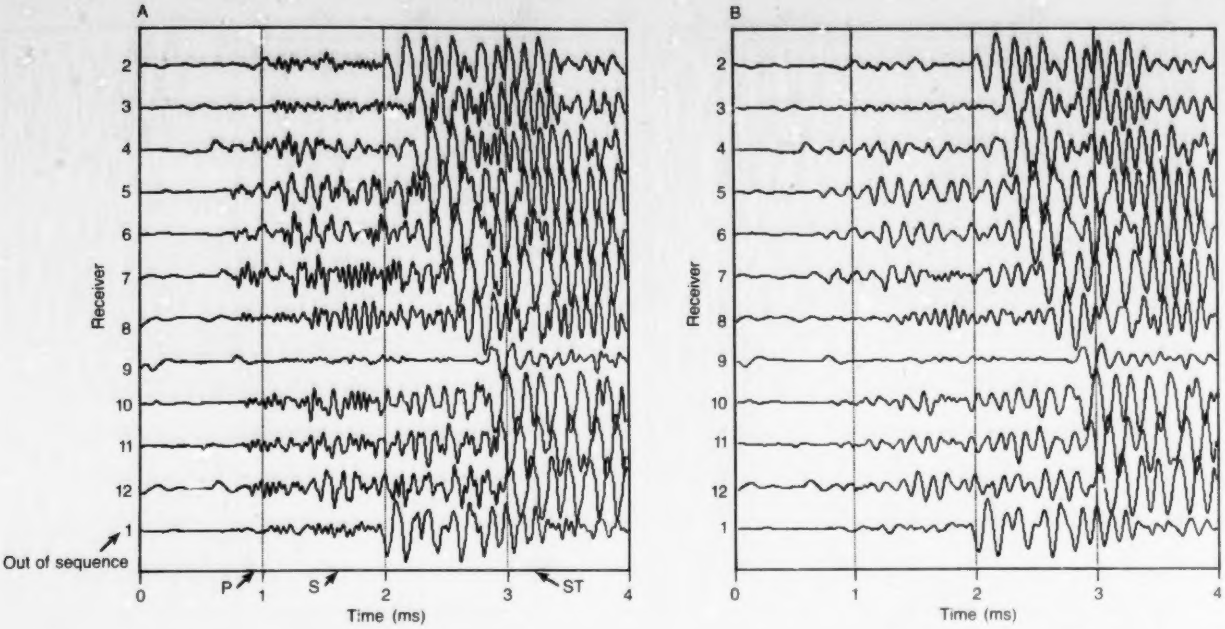

Figure 82. A. MCS waveforms recorded at 126 mbsf by asynchronous computer control (Note that receiver 1 is recorded at the farthest offset location and that compressional (P), shear (S), and Stonely (ST) arrivals occur near those at receiver 2). B. Bandpass filtering of the waveforms show the dominant received frequency band as 2.5 to 17.5 kHz.

ciently separated for velocity analysis using this geometry. Compressional (*P*), shear (*S*), and the later-arriving Stoneley (*ST*) wavemodes are identified. In addition, this example shows the misordering of receiver 1 to the farthest offset as a result of asynchronous recording. The waveforms were recorded based on the pick of the high-amplitude Stoneley/fluid arrival.

Figure 82B shows the same suite processed using a frequency filter to eliminate high-frequency noise and low-frequency instrument bias. A Butterworth bandpass operator was convoluted twice with each waveform to ensure a zero-phase outcome. The dominant frequency band of the waveforms is 2.5–17.5 kHz, as shown by a comparison of the unfiltered with the filtered waveforms, and is considerably lower than the peak source output band resulting from propagation losses through the formation and borehole. The data for the entire interval were processed using this filter before semblance analysis.

An expanded time scale for a suite of waveforms recorded at 214.4 mbsf is shown in Figures 83A and 83B. The high-amplitude shear arrival is prominent near 1250 $\mu$s at receiver 1 and 1700 $\mu$s at receiver 12; however, the compressional arrival is emergent only for the longer source-receiver offsets. This may result from both poorer sensitivity of MCS receivers 1, 2, 3, and 9 and from better far-field wave-mode separation farther from the source. Receivers 4, 5, 6, 7, 8, 10, 11, and 12 thus were used in the compressional semblance computation, and the others were rejected over the entire interval.

The MCS and LSS data were processed for compressional and shear velocities using a modified semblance calculation to correlate energy traveling over the receiver array at progressive time steps. Peak semblance occurs when the time lag equals the receivers offset, divided by the velocity. Compressional- and shear-wave velocities were calculated separately by restricting the time window of correlation over the wavefield and the range of possible velocities. For additional discussion of semblance processing for sonic waveforms, the reader should consult Kimball and Marzetta (1984) and Goldberg and Gant (1988).

Semblance results for LSS data are plotted as a function of depth in Figure 84. Compressional, shear, and Stoneley slowness values (the inverse of velocity) in microseconds per foot and the peak compressional amplitudes in millivolts for 2.44-, 3-, and 3.81-m receivers also are shown. The LSS log is unreliable in the intervals from 140 to 160 mbsf and 380 to 450 mbsf because of the shorted cable head. Elsewhere, mean compressional, shear, and Stoneley velocities are reliable and equal to about 6.5, 3.5, and 1.5 km/s, respectively. Of particular interest is that compressional and shear slownesses increase (velocities decrease) and compressional amplitudes decrease in the upper 140 mbsf, which suggests that physical-property variability is scattering energy in this interval. Below 140 mbsf, the MCS compressional-wave velocity is inverted and plotted on scale with the LSS log for comparison. MCS velocity and semblance curves are indicated by heavy lines. The correlation of MCS and LSS velocities is generally good in the overlapping zones, and the semblance correlates roughly with changes in compressional amplitude. The low amplitudes observed in the upper interval of the hole suggest that the MCS data also may be expected to have lower semblance values in the upper interval owing to formation changes.

Figure 85 depicts the processed MCS semblance velocity logs. $V_p$ varies from 5.0 to 7.5 km/s over the interval, and peak semblance varies between 0.10 and 0.75, where a value of 1.0 represents perfectly coherent signals. Low semblance (less than 0.15) is used to discriminate against unreliable velocities that are not plotted. This generally occurs when the shear wave is severely attenuated by fracturing or borehole washout. $V_s$ is less variable than $V_p$ because of the proportion of sonic energy partitioned into the guided-wave modes in fast formations that dominates the group velocity (Paillet and White, 1982). These logs were

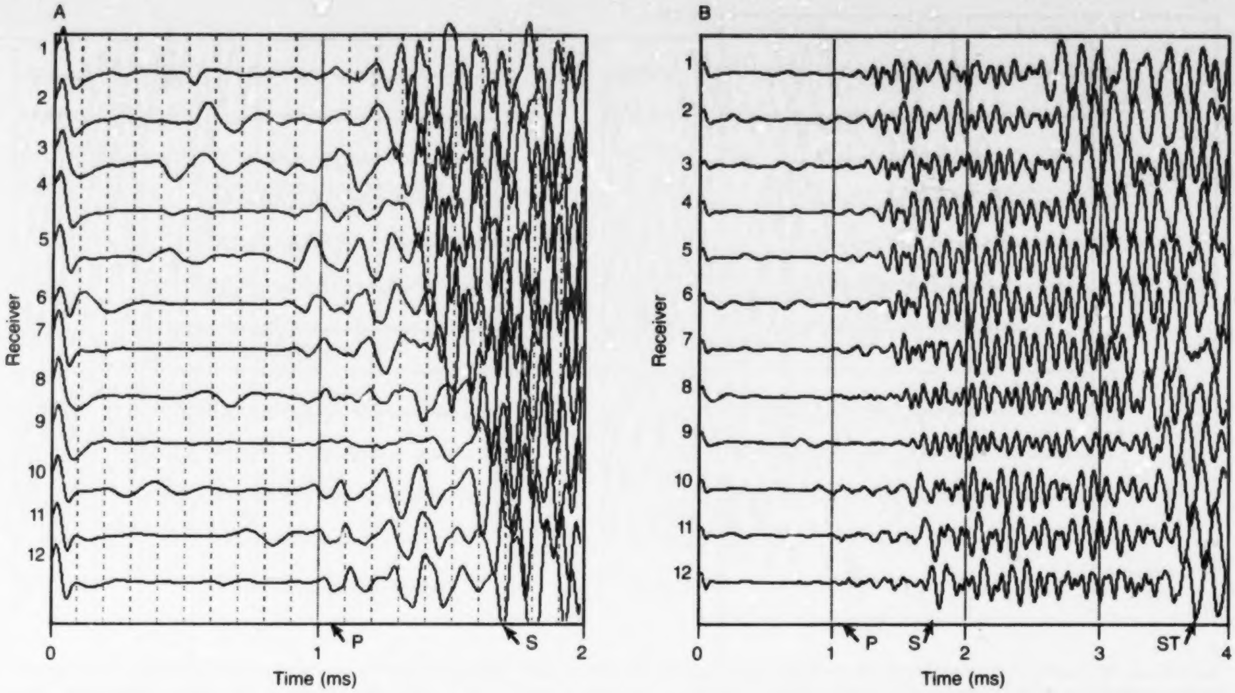

Figure 83. A. Filtered MCS waveforms recorded at 214.4 mbsf show that compressional arrivals (P) have low amplitude at the nearest receivers. B. Full 4-ms time scale shows strong shear (S) and Stoneley (ST) arrivals at all receivers.

smoothed using a ± 0.9-m boxcar filter. The smoothing filter is shorter than the receiver span and thus does not influence the vertical resolution of velocity.

The $V_p/V_s$ ratio is primarily governed by the compressional velocity and varies about a mean of 1.9 (Fig. 85). Variable $V_p/V_s$ ratios and reduced semblance values occur in the foliated interval above 140 mbsf and are probably due to scattering losses in zones of deformation (see "Metamorphism and Alteration" section, this chapter). The most dramatic localized decreases in shear semblance and compressional velocity appear to be associated with isolated fractures that may occur near 275, 310, and 335 mbsf (see "Borehole Televiewer" section, this chapter). This correlation also might be used to predict the occurrence of fractures near 95, 135, and 195 mbsf, where the borehole televiewer data have not yet been processed. Further analysis of the sonic logs may reveal detailed correlation as well as subtle changes in lithology and physical properties in oceanic layer 3.

## VERTICAL SEISMIC PROFILING

### Introduction

A vertical seismic profile (VSP) differs from a conventional reflection profile in that the receiver is clamped successively at different borehole depths within the earth (Fig. 86; Hardage, 1983; Balch and Lee, 1984). The seismometer records both the direct, downgoing waves and upgoing waves reflected from acoustic impedance changes below the clamping depth. Interval velocities may be calculated from the difference in arrival time of the direct wave between different receiver depths. Processing techniques can be applied to separate the upgoing and downgoing wavefields, which can then be analyzed for attenuation properties of rock, prediction of acoustic properties below the bottom of the hole, and correlation with borehole lithology, wireline logs, and events on conventional seismic-reflection profiles. Resolution of structure is limited by the signal/noise level, bandwidths of source and receiver, and rock velocity. In marine usage, the frequency of the source ranges from 5–30 Hz (air guns and explosives) to about 120 Hz (water gun). In rocks having velocities of 4–8 km/s, the finest scales resolvable (about one quarter wavelength) with a broad band receiver under good signal/noise conditions are 8–200 m.

### Objectives

The purpose of Leg 118 was to drill in or near an oceanic fracture zone offsetting a slow-spreading ridge to sample igneous and metamorphic rocks from the lower oceanic crust and upper mantle. The VSP for Leg 118 was planned (1) to provide seismic interval velocities with which the rock sequence drilled could be put into the context of seismic-refraction velocity structure of oceanic crust in general (Spudich and Orcutt, 1980; White, 1984; Bratt and Purdy, 1984) and fracture zones in particular (Detrick and Purdy, 1980; Cormier et al., 1984), (2) to estimate fracturing on scales greater than 0.5 m by comparing seismic interval velocities with velocities measured in the laboratory using core samples and measured *in situ* by sonic logging tools, (3) to correlate borehole lithology with the upgoing seismic reflected wavefield, (4) to predict structure and lithology changes below the drill hole, and (5) to estimate physical properties of rock on seismic scales by studying particle motion and downhole seismic attenuation.

### Previous Oceanic Borehole Seismology

VSPs are a standard industry tool used most often to tie surface seismic-reflection profiles to borehole geology and logs (Gal'perin, 1974; Hardage, 1983; Balch and Lee, 1984). In scientific ocean drilling, oblique seismic experiments were conducted during DSDP Legs 52, 65, 70, 78B, 88, and 91 and during ODP Leg 102 to investigate the seismic structure of upper

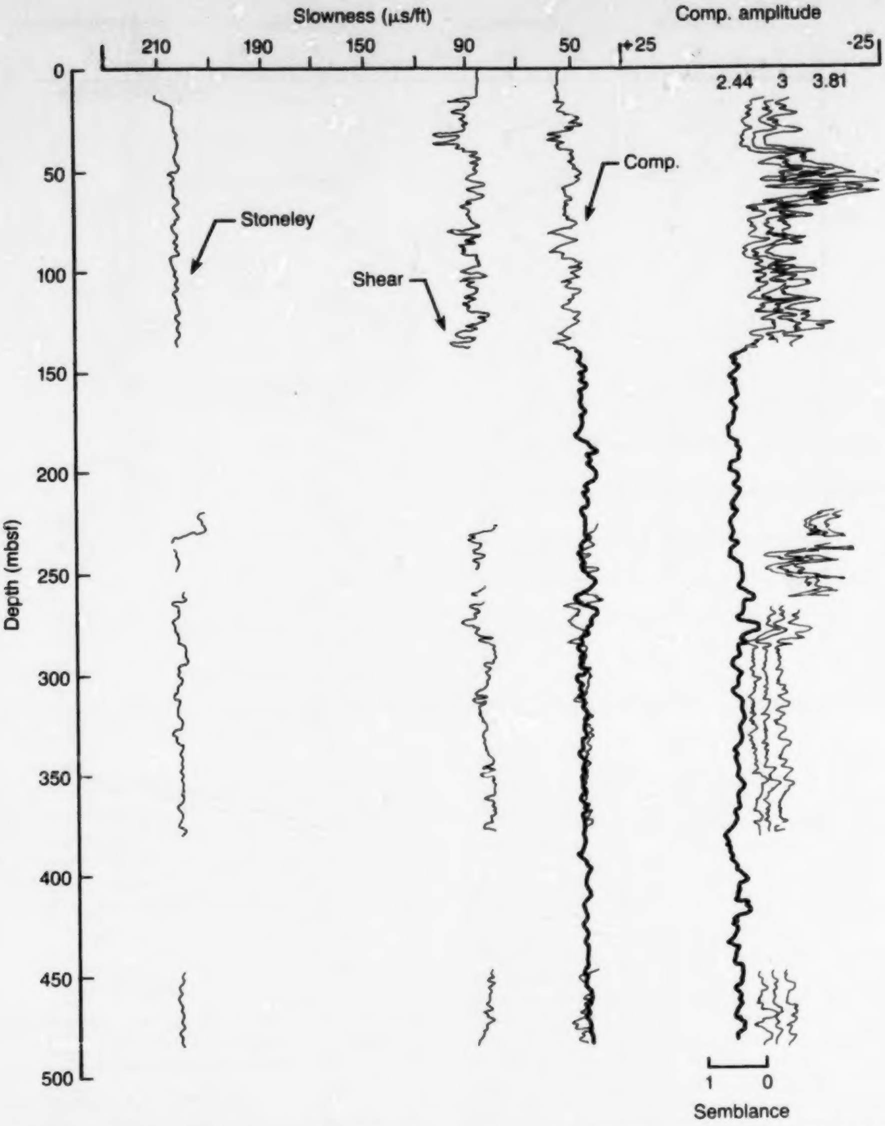

Figure 84. Compressional, shear, and Stoneley slowness (inverse of velocity) by semblance analysis of LSS waveforms. Electrical shorting in the tool caused the loss of data from 140 to 260 mbsf and from 380 to 450 mbsf. The MCS compressional slowness and semblance curves (heavy curves) are shown for comparison and are in general agreement with the LSS slowness and relative amplitudes, respectively. Compressional and shear slownesses increase and compressional amplitudes (in millivolts) decrease in the foliated gabbro interval (40–140 mbsf). Stoneley velocity remains constant at about 1.4 km/s over the entire interval.

oceanic crust (Stephen, 1979, 1983; Stephen et al., 1983; Jacobson et al., 1984; Little and Stephen, 1985; Shipboard Scientific Party, 1986; Duennebier et al., 1987; Swift et al., in press). In these experiments, a three-component borehole seismometer was clamped at one to five depths within oceanic basement, while a second ship fired airgun and explosive shots in radial lines and concentric circles around the drill ship. Conventional zero-offset VSPs were performed in oceanic basement during ODP Legs 104 and 111. These VSPs rigorously confirmed correlation of sub-basement seismic reflectors with borehole lithology and predicted the presence of significant changes in acoustic impedance below the total depth drilled (Shipboard Scientific Party, 1987, 1988a).

### Setting

Hole 735B is located in 720 m of water on top of the fracture zone ridge that forms the eastern wall of the Atlantis II Fracture Zone (see "Geologic and Tectonic Setting" section, this chapter). Unprocessed, single-channel seismic profiles across the ridge crest, collected during the *Conrad* site survey and the site approach by *Resolution* (see "Operations" section, this chapter) could resolve no sediment above acoustic basement and no sub-basement reflectors in the area of Hole 735B. No refraction studies have been conducted on the eastern transform wall.

In general, not much is known about the seismic structure of fracture zone ridges. At the Kane Fracture Zone, delay-time

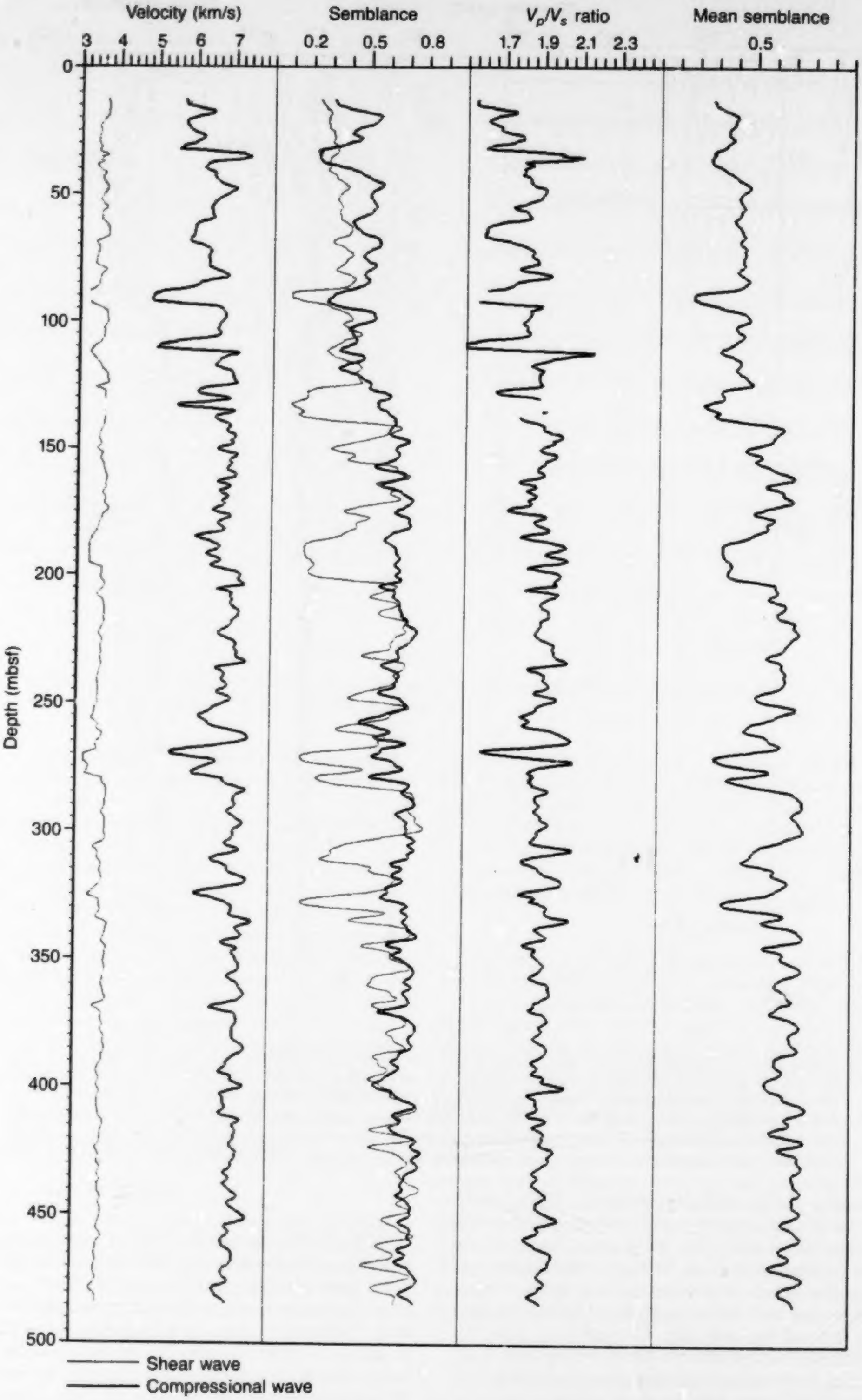

Figure 85. Compressional and shear velocity logs from 13.0 to 484.6 mbsf in Hole 735B. Peak semblance (see text) and $V_p/V_s$ also are shown. Low velocities and semblance occur in isolated intervals below the iron-titanium oxide gabbro (265–285 mbsf) and in the foliated gabbro (40–140 mbsf) where localized fracturing or deformation occurs.

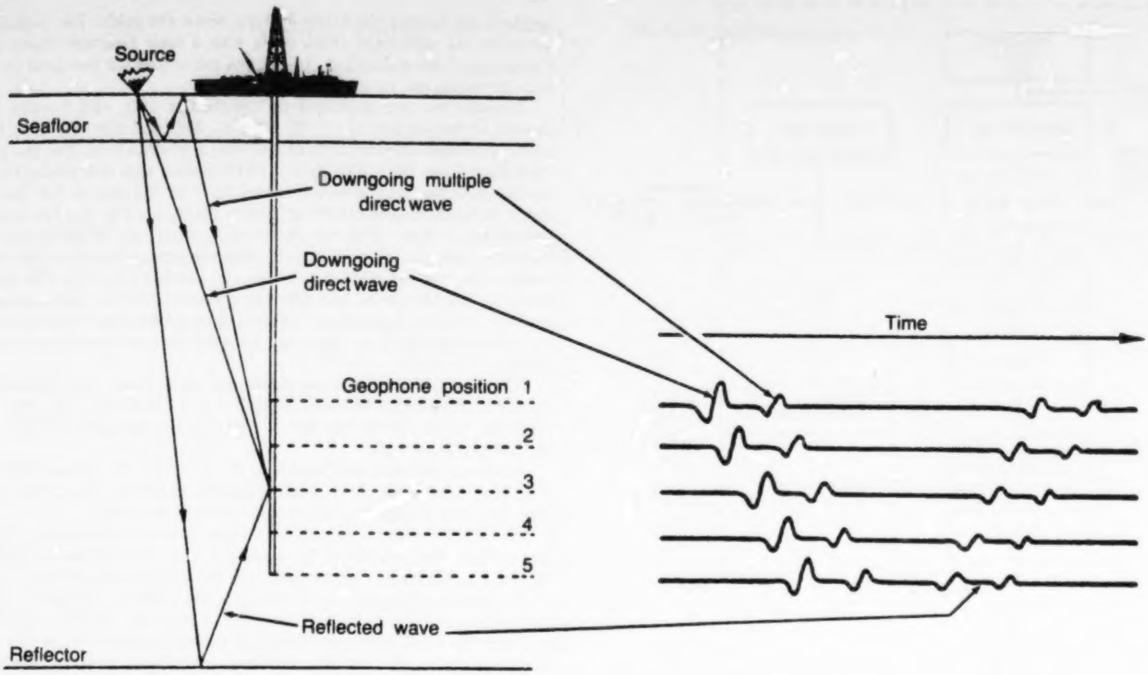

Figure 86. Schematic diagram of VSP geometry and record section illustrating how direct and reflected arrivals differ with changes in receiver depth. (Modified after Mons and Barbour, 1981).

analysis of refracted arrivals passing beneath the northern fracture zone ridge found high velocities (7.7–8.0 km/s) at shallow depths (3–4 km bsf) (Detrick and Purdy, 1980; Cormier et al., 1984). Structure within the ridge itself could not be resolved with the data. Similar results were found at the Oceanographer Fracture Zone using refraction methods (Sinha and Louden, 1983).

## METHODS

Two seismic logging tools were used to collect VSPs during Leg 118: the Schlumberger Well Seismic Tool (WST), a vertical-component seismometer, and the WHOI three-component seismometer.

### Vertical-Component Seismometer

The Schlumberger WST contains four vertically oriented, 10-Hz geophones wired in series and a single-step preamplifier (60 dB). The signal is transmitted via the seven-conductor logging cable to the Schlumberger CSU logging data acquisition system. Signals were recorded for 3 s at a sampling rate of 1 kHz with no deep-water delay using both air- and water-gun sources (described next). At each receiver clamping depth, air- and water-gun shots (5–25 each) having a good signal/noise ratio were recorded and stacked. Transit time to the first arrival was detected by Schlumberger software and recorded with the stacked data on digital tape. Plots of the seismograms could not be provided on board ship because of time constraints. Later, the data tapes will be converted from Schlumberger LIS format to SEG-Y at the Lamont-Doherty Borehole Research Laboratory for further processing.

### Three-Component Seismometer

The acquisition methods used during Leg 118 with the WHOI three-component tool were similar to those used in the oblique seismic experiments from earlier ocean drilling legs (Stephen, 1979; Shipboard Scientific Party, 1988a, 1988b).

### Receivers

The receiver used was a Geospace Wall-Lock Seismometer with a three-channel preamplifier that can be remotely stepped through six gain settings in increments of 12 dB. Optimally, signals are sent up the logging cable with a maximum amplitude of 25 V peak-to-peak. The sensing package consists of three sets of two 4.5-Hz geophones wired in series and aligned vertically and horizontally in two orthogonal directions. The geophones have a flat response at 4.5 to 100 Hz. After preamplification, the three voltage signals are sent via the seven-conductor, 10,000-m-long logging cable to the logging winch aft of the pipe racker on the helicopter deck of the *Resolution* from which they are patched into the data acquisition system in the Underway Geophysics Laboratory (UGL) (Fig. 87). Receiver depths are read from the meter wheel in the logging winch hut. To monitor the far-field source signature of the guns, an A-1 hydrophone with a preamplifier gain of +20 dB was suspended at a depth of about 250 meters below sea level (mbsl) from the starboard tautline mooring boom abeam the moon pool (Fig. 88).

Unlike VSPs run during Legs 104 and 111, the pipe could not be clamped off in the reentry cone. Because the hole was not cased and was located off center of the hard-rock guidebase, clamping the pipe into the reentry cone increased the risk of losing the bottom-hole assembly.

### Recording Systems

Three signals from the seismometer and one from the hydrophone were recorded in the UGL in two ways (Fig. 89). The primary acquisition system was the ODP digital logging program HI-RES (M. Weiderspahn, Univ. of Texas, Austin) installed in a Masscomp M-500 minicomputer. After analog gain adjustment with an Ithaco Model 445 amplifier, the signals were passband filtered (Wavetek filter) between 1 and 250 Hz (115 dB per octave rolloff) to prevent aliasing and to eliminate low-frequency noise. Each of four channels was digitized at 100 Hz and stored as 32-bit IBM floating-point data in SEG-Y format on nine-track magnetic tape. A total of 4 s of signal in each channel was recorded after a sequence start and field time-break signal generated by the "Black Box" (Fig. 90).

An eight-channel Hewlett-Packard Model 3968A audio tape recorder was used as a backup recording system (Fig. 89). Four seismic signals were recorded (on 1/4 in. tape at 3-3/4 in./s) in FM channels, while time code and field time break from the blast phone were recorded on two direct channels.

### Testing and Calibration

Before the experiment, we tested the attenuation effect of the seven-conductor cable in the frequency passband used by the VSP (5–250 Hz).

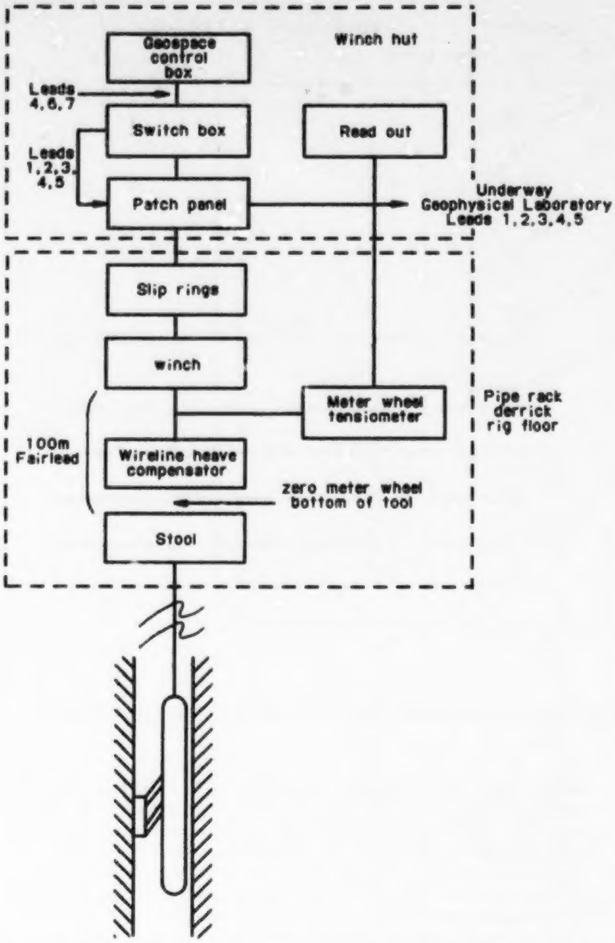

Figure 87. Block diagram of components outside the Underway Geophysics Labortory (not to scale).

### Logging Cable Attenuation

Specific details of the ODP logging cable are as follows:

1. Vector Cable Company, Type 7-46P, seven conductors, torque-balanced, double-armored logging cable.
2. Condition: new, unused.
3. Length: 31,497 ft.
4. Resistance of each conductor per 1000 ft: 10.3 ohms. Resistance of total length: 330 ohms.
5. Capacitance of each conductor to the two layers of armor per 1000 ft: 0.04 $\mu$farads. Capacitance for total length: 1.27 $\mu$farads.
6. The "RC" time constant of the cable from its resistance and capacitance is 0.43 ms or a frequency response of 2.3 kHz.
7. The cable is wound on a reel having a 22-in. diameter drum (62 in. outside diameter, 50 in. wide).

The test was conducted in the ODP logging winch hut with the following setup: A Wavetek Model 191, 20 MHz Pulse/Function Generator with a 50-ohm output was connected to the inboard (ship) end of the cable. Its level was set at a maximum 30 V, less the 10-dB switch, which gives about 9.6 V peak-to-peak. A two-channel Tektronix Model 485 oscilloscope was used to monitor the input to the cable from the Wavetek function generator and the output from the outboard (tool) end of the cable. The inboard end passes through a set of slip rings. The outboard end is "headed" with a Schlumberger torpedo connection (using the BCC connector). A 1.5-m-long pendant of additional cable terminates in a Gearhart-Owen female seven-pin connector assembly. Wiring connections are labeled clockwise looking down the cable. For measuring purposes, an additional patch cable with a male Gearhart-Owen connector and Cannon 2-1/2 in. 10-banana pin connector was used to lead into the winch hut to the oscilloscope.

Amplitudes were measured on conductors 1, 2, and 3 using 5 as ground at frequencies of 10, 20, 50, 100, 200, and 500 Hz; 1, 2, 5, 10 kHz into a high-impedance load and into a 50-ohm load. For the high-impedance load, the 1/e point at 2.3 kHz agreed with that predicted. No measureable loss was observed up to 200 Hz; the loss at 500 Hz was about 10%, increasing to 89% at 10 kHz (Table 12, Fig. 91). No discernable 60 Hz or other noise was observed on the traces. With 50-ohm terminating load, the input loaded the signal generator heavily at the lower frequencies, but the cable losses were comparable (Fig. 91). The rolloff began at 200 Hz (20%) and was faster because of the load resistance shunting the line capacitance. Given the small amount of pickup with the high-impedance load, there was no need for a low-impedance termination.

The cross-talk between connectors (unterminated) was measured at the same frequencies between leads 2 and 3 (Table 12, Fig. 93). The cross-talk up to 100 Hz was about 0.085%, increasing to 0.1% at 200 Hz and 1% at 500 Hz.

Results of this test indicated that the 5- to 250-Hz signals from the three geophones in the WHOI seismometer can be run through the cable with little loss of signal or cross-talk between channels.

Also, before conducting the VSP experiment, the complete acquisition system was calibrated by passing a sine wave signal of various known frequencies and amplitudes into the seismometer above the geophone package, through the cable, and into both the HI-RES acquisition system and the audio tape recorder. The results of this calibration will allow us (1) to compare accurately between amplitudes in different channels, (2) to plot particle motions, and (3) to analyze downhole losses in the pressure field quantitatively. The high level of electrical noise on board the ship required considerable care in shielding and grounding, particularly in cases where single-point grounding was not feasible.

### Seismic Sources

Two seismic sources were used to discriminate true seismic response of the earth from structure produced by spectral characteristics peculiar to a particular gun type. Following methods used by J. Phillips during ODP Legs 104 and 111 (Shipboard Scientific Party, 1987, 1988b), both air and water guns were suspended from a pair of Norwegian floats (Fig. 92). A Bolt Model PAR 1500 air gun having a 1000-in.$^3$ chamber and an SSI P400 Model 2 water gun having a 400-in.$^3$ chamber were hung with vent ports at 8.7 and 4.8 mbsl, respectively. Gun depths for the experiment were chosen after measuring far-field waveforms with the gun suspended at depths from 1.5 to 11.3 mbsl, using the source monitor hydrophone at a depth of 250 mbsl (Fig. 93). Both guns were operated at 1900 psi (higher pressure shots might damage ship thruster seals). A blast phone for detecting the shot instant was rigged 5.5 mbsl, below the water gun, but was not used during most of the experiment because of a malfunction in the timing signal system. The buoys were moored to the drill ship's aft port crane (Fig. 94). In this position, the sources were 38 m aft of the drill string, 39 m to port of the drill ship's centerline, and 53 m diagonally from the center of the moon pool. The horizontal separation between the blocks from which the hydrophone and guns were hung was about 80 m, but the actual gun-to-hydrophone distance may have varied as much as 8 m owing to currents. Because gun depth remained relatively fixed with respect to the sea surface, the source signature, which includes the reflection of the pressure field from the sea surface, remained relatively constant.

The guns were not fired simultaneously. At each receiver clamping depth, sequences of about 5–10 air-gun shots alternating with 5–10 water-gun shots were fired. Tests performed during Leg 111 comparing gun performance rigged alone and in tandem showed that the most significant shadow effects of rigging the guns on the same vertical mooring were an increase of about 5% in the peak pressure of the air-gun radiated pulse and a slight decrease in the water-gun peak pressure pulse (Shipboard Scientific Party, 1988b). During the Leg 111 test, there was no significant change in the frequencies of the guns' primary or bubble pulse.

### Processing

Seismic data from the VSP were processed in the *Resolution's* computing center on a VAX 11/750 minicomputer. The SEG-Y tapes gener-

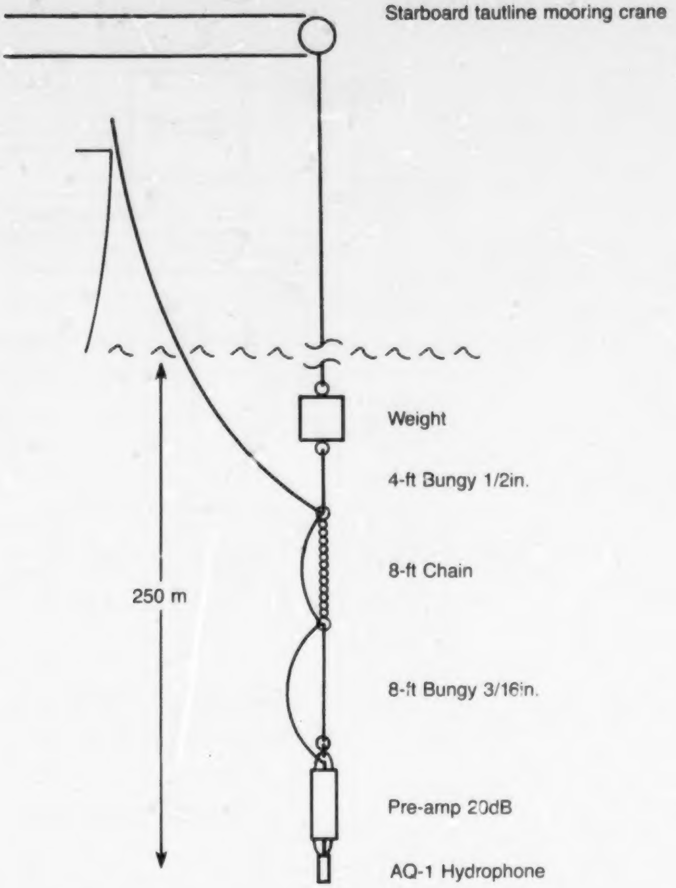

Figure 88. Schematic diagram of source monitor mooring (not to scale).

ated on the MassComp acquisition computer were reformatted to ROSE format (LaTraille, 1983) to use processing programs developed by the seismology group at WHOI. During reformatting, the gun type, gun depth, and seismometer depth below seafloor were merged into the ROSE shot headers. Shots were sorted by gun type and receiver depth and then stacked. The first arrivals of the direct wave were selected visually using a computer display and cursor program. Following standard VSP analytical procedures (Hardage, 1983; Balch and Lee, 1984), seismograms were plotted vs. depth before and after offsetting the seismograms by the direct-wave arrival time.

## Navigation and Weather

The Honeywell Automatic Station Keeping (ASK) system is designed to position the *Resolution* within a horizontal offset from the hole of 1% to 1.5% of the water depth. Thus, at Hole 735B the drill pipe was nominally maintained within 10 m or 0.6° of the vertical above the receiver. Because of good weather, the deviations during the experiment were only 0 to 2 m, as determined from the ship's Honeywell ASK system. Sea state was 0 to 1 and wind was 5–10 kt from the west-northwest. A slight 8-s period northerly swell existed, and heave on the drill-pipe compensator was about 0.6 m. Ship's heading for the whole series of experiments was N36°E. The angular offset of the source was about 3.2° from the vertical above the guidebase. The Honeywell ASK system determines horizontal offsets between the ship and hole by comparing traveltime differences to four transducers lowered 5.5 m below the ship's hull from a Datasonics seafloor beacon and by logging the ship's heading every second. We stripped 1-min data from the ASK tapes. Transit satellite fixes, where available, also were recorded.

## Operations

The VSP was scheduled near the end of logging operations in case failure of the clamping arm caused blockage and we had to abandon the hole. Considerable difficulties were initially encountered when acquiring data with the three-component seismometer. On 8 December, the tool was run into the hole, signal levels were tested, and gain levels on the tool and laboratory amplifiers were set to allow complete resolution during recording of the signal without clipping. Data were acquired at two clamping points near the bottom of the hole. On the third clamping, the signal deteriorated into random, high-amplitude fluctuations. We suspected malfunction of the pre-amplifier. The tool was pulled, and a backup tool run into the hole. The clamping arm on the second tool failed to open, and that tool also was pulled to continue other logging operations.

Both tools were opened and restored to apparent functioning condition in the downhole measurement laboratory. Eleven hours later, the first tool was run into the pipe, where it failed again. The backup tool failed to open its clamping arm on deck. On the morning of 9 December, the Schlumberger tool was run into the hole. The guns were rerigged to include a Schlumberger shot-detection blast phone and gun-triggering connections. Noise

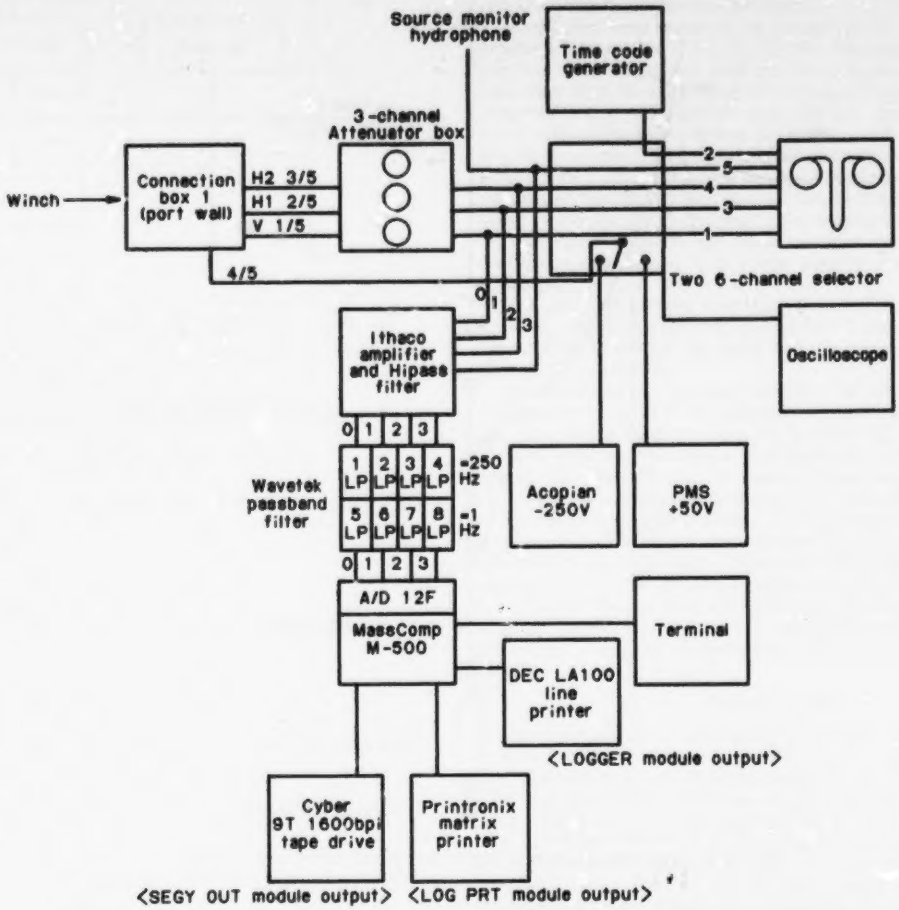
Source monitor hydrophone
Time code generator
3-channel Attenuator box
Winch
Connection box 1 (port wall)
H2 3/5
H1 2/5
V 1/5
4/5
2
5
4
3
1
0
1
2
3
Two 6-channel selector
Ithaco amplifier and Hipass filter
Oscilloscope
0 1 2 3
1 LP
2 LP
3 LP
4 LP
=250 Hz
5 LP
6 LP
7 LP
8 LP
=1 Hz
Wavetek passband filter
Acopian -250V
PMS +50V
0 1 2 3
A/D 12F
MassComp M-500
Terminal
DEC LA100 line printer
<LOGGER module output>
Cyber 9T 1600bpi tape drive
Printronix matrix printer
<SEGY OUT module output>
<LOG PRT module output>

Figure 89. Schematic diagram of the processing and recording components in the Underway Geophysics Laboratory for signals from the WHOI three-component seismometer.

problems similar to those sustained by the first WHOI seismometer were initially encountered at several depths. The trouble was finally diagnosed as tool slippage on the smooth walls of the borehole. When the tool was dragged up the hole a short distance at each clamping, a firm clamp to the walls was achieved. The cable then was slacked 2 m. The tensiometer was monitored to see if the tool slipped. The change in load that occurred when the tool was adequately clamped could be better detected when not using the wireline heave compensator. The entire hole was logged at 20-m increments, and the tool recovered in good condition.

The three-component tool was then redeployed using the new clamping procedure. At the first depth, the tool was clamped firmly, and a good signal was received. The entire hole then was logged with a total of 329 air- and water-gun shots to 22 receiver depths (in addition to the two depths occupied on 8 December) in 15- to 25-m increments. In addition, background noise was recorded for 1–2 min with both guns off at six tool locations (29, 44, 74, 174, 249, and 394 mbsf). Data were also intentionally recorded while the pipe was raised and lowered to assess the signal spectrum of noise generated by pipe motions. Qualitatively, the background noise increased as the tool approached the bottom of the drill pipe, which was suspended 12 m into the hole. The pipe appeared to make more noise at 5 m than at 12 m in the hole. This was corroborated by greater flexual motion observed on the video camera suspended immediately above the guidebase. In all, VSP operations lasted about 25 hr in the hole (Table 13).

### Results and Discussion

During shooting to the two deepest WHOI receiver depths on December 8, the blast phone was used to detect shot instants and initiate the recording sequence. During shooting to the WHOI seismometer on 9 December, however, shot instants could not be determined using the blast phone signal; thus a constant, internal time break was used to trigger recording of the HI-RES system before the gun fired. The delay between the time of the first sample and the shot instant was determined by comparing average traveltime to the hydrophone for shots using the blast phone with traveltime for shots without the blast phone. The

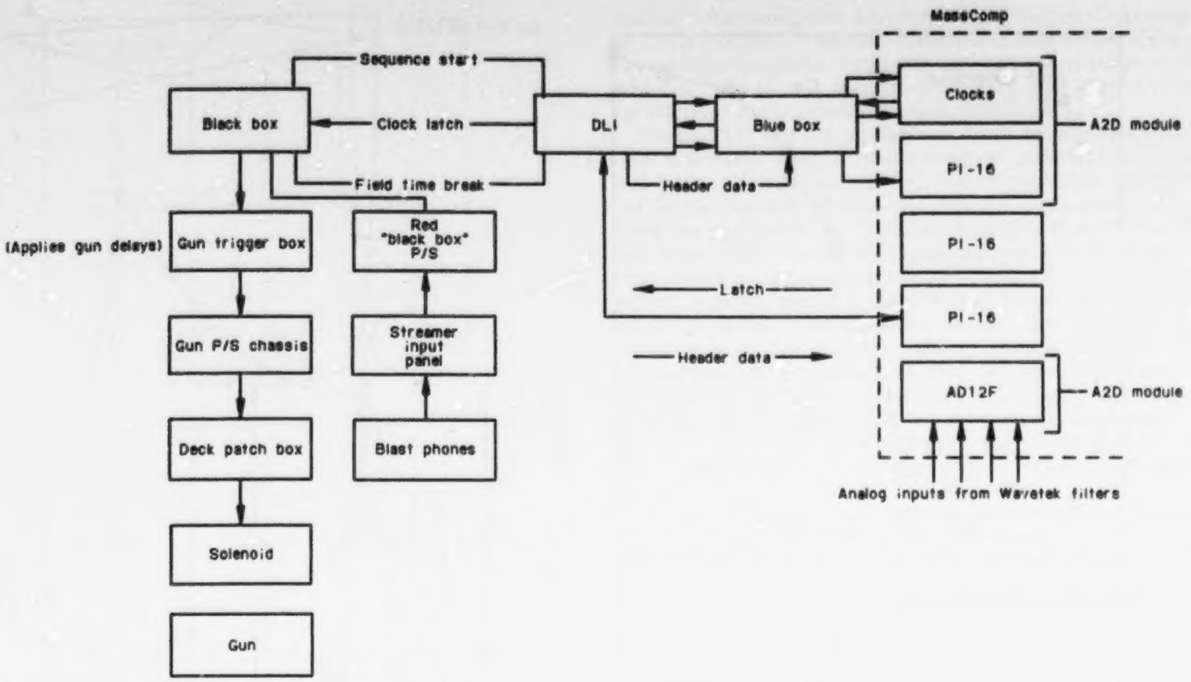

Figure 90. Timing signal flow in the Underway Geophysics Laboratory. P/S = port and starboard; DLI = data logger interface; clock = clock interface board; PI-16 = 16-bit parallel interface board; AD12F = analog to digital converter, 12-bit resolution; A2D = software aquisition module for analog to digital controller.

**Table 12. Downhole time required for vertical seismic profiling.**

| Date (1987) | Time | Activity |
|---|---|---|
| 8 December | 5 hr 30 min | Log bottom 20 m of hole. Both 3-component tools fail. |
| 8 December | 2 hr | Rerun WHOI tools. Both tools fail. |
| 8 December | 11 hr 30 min | Schlumberger 1-component tool. Log entire hole. |
| 9 December | 5 hr 45 min | WHOI tool. Finished logging upper 480 m of hole. |

differences in traveltimes for water and air guns (0.073 and 0.075 s, respectively) were applied as static corrections to the stacked shot files.

Most of the data on the vertical channel using either gun are of good quality and have fair signal-to-noise characteristics. Figure 95 indicates for each gun type an example of the data in each of the four channels. Figures 96 and 97 show the stacked record sections for air and water guns, respectively. Random noise is more common at depths below 350 mbsf and exceeds the signal level in some shots. Because tool clamping took longer at these depths, we suspect that the noise was caused by slow slippage of the tool. The caliper log indicated that the hole was smoother at depth.

Data from the horizontal channels are generally ringy with few, if any, distinct events after the first arrival. Since little noise preceded the first arrival, pipe banging is not a likely source. The ringing may be horizontal oscillation of the tool set up by the passage of the compressional wave.

Coherent noise is the most significant problem when identifying coherent reflectors in the record sections. The air-gun signature has strong bubble pulses at 0.1 and 0.2 s after the primary pulse. Later arrivals were obscured by a water bottom multiple that arrived at about 1.5 s (Figs. 96 and 97). When the data are shifted by subtracting the one-way traveltime to the receiver (Fig. 98), the downgoing wave trains are aligned. Two additional water bottom multiples are apparent at about 2 and 3 s. Post-cruise processing of the signal using source signature deconvolution with the hydrophone recordings of the outgoing pulse may supress coherent noise.

The traveltimes selected from the vertical component of the stacked seismograms for both VSP runs are presented in Tables 14 and 15 and Figure 99. The waveform and phase of the initial arrival was similar at all receiver depths. Sources of error include a small systematic uncertainty in shot time (+0.004 s, 95% confidence limit). Additional sources of error are imprecision in selecting arrivals in seismograms and obscuring of the first arrival by noise. These random errors contribute +0.006 to 0.008 s. Thus, total systematic and random error is about +0.010 to 0.012 s. Traveltime differences between receiver clampings spaced 20 to 25 m apart are about 7 to 8 ms. Because errors in transit times are twice the time differences, little significance should be given to incremental gradient changes between clampings in Figure 99.

The vertical channel traveltime data sets from VSPs with the three-component tool and the Schlumberger tool are consistent. The slopes of both traveltime curves are relatively constant downhole. Straight lines were fit by least squares to the individual water- and air-gun data sets and to all traveltimes from each receiver (Table 16). There are no significant differences between traveltimes selected from air- and water-gun data. When all data are included, the slopes of the single and three-component tool data are similar: 6.38 and 6.51 km/s, respectively. The 95% confidence limits of the slopes determined in the better constrained data sets are about ±0.15 km/s. These velocities are consistent with velocities measured on hand samples that are representative of the general lithology (see "Physical Properties" section, this chapter). Fracturing on scales much greater

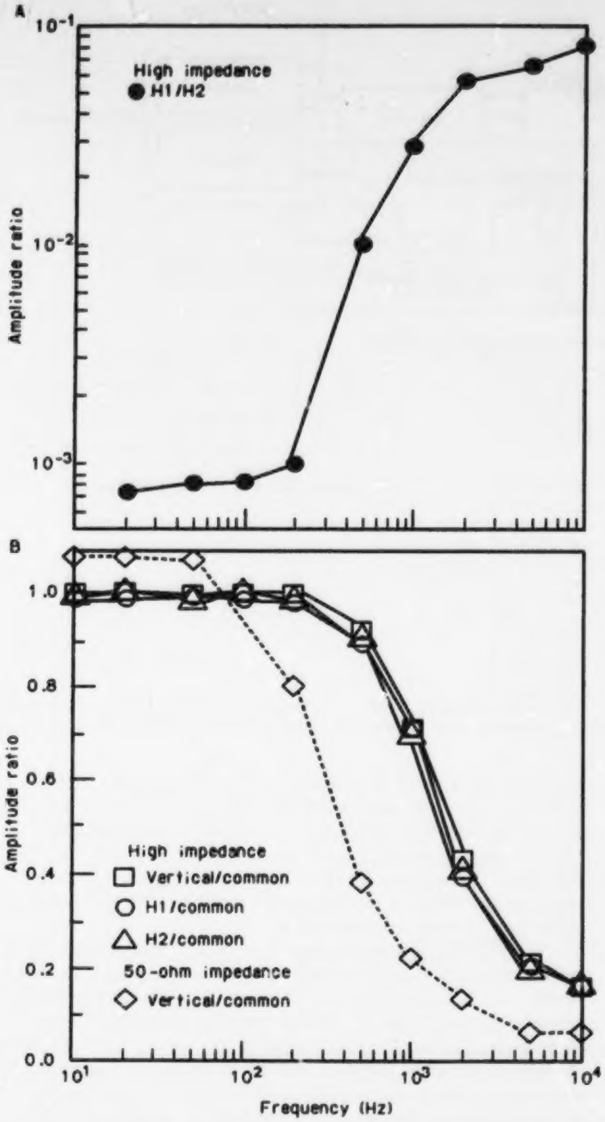

Figure 91. A. Amplitude ratio of high-impedance load. B. Amplitude ratio of 50-ohm impedance load.

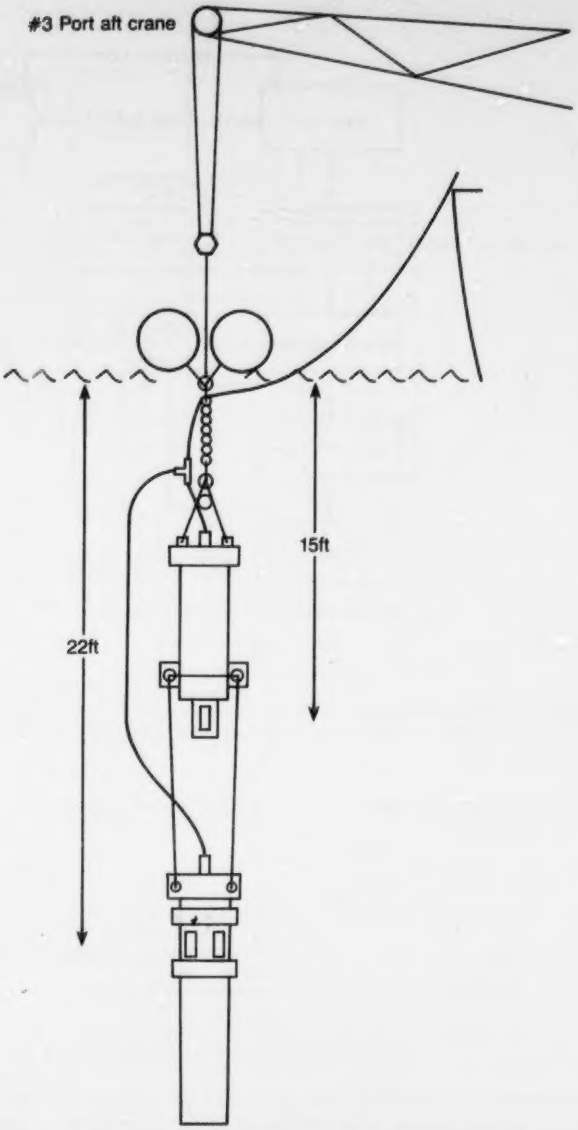

Figure 92. Schematic diagram of gun mooring (not to scale).

than that resolvable by core studies, which would have the effect of reducing seismic velocities relative to laboratory measurements, appears to be relatively insignificant at Hole 735B.

In Figure 100, the stacked air-gun data are offset by the traveltime to the first arrival; thus, the upgoing reflections from below the seafloor are aligned at their two-way traveltimes. Record sections with and without automatic gain control (AGC) scaling are shown. Most of the coherent signal dips and thus can be considered coherent noise. At about 1.4 s in the AGC seismograms from the shallowest seismometer depths, the reflector amplitude decreases and cannot be distinguished from the downgoing compressional-wave train. Any reflectors earlier than this event are too weak to be resolved without further processing, as compared to the high-amplitude downgoing pulse.

The reflector occurs about 0.3 s after the first arrival to the shallowest receiver depth. Allowing for two-way traveltime and using a velocity of 6.5 km/s, the reflector occurs at about 1 km below the seafloor. This places the impedance change causing the event at about 4 km above the floor of the fracture zone. Speculatively, the event might be a reflection off a fault surface or a 50- to 200-m-thick transition in physical properties or lithology. The possibility cannot be excluded with these data that the event marks upwelling mantle, as suggested by the high velocities found below the Kane Fracture Zone ridge (Cormier et al., 1984).

## Conclusions

Seismic velocities are uniform on the scale of 50–200 m throughout Hole 735B. Seismic velocity averages 6.4–6.5 km/s.

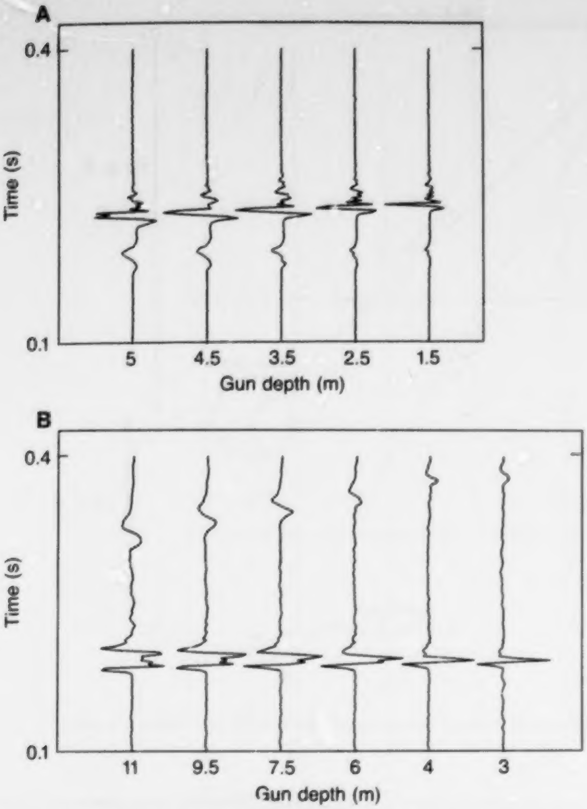

Figure 93. Gun signatures, received by source monitor hydrophone at 250 mbsl, as a function of nominal port depth. A. Water gun. B. Air gun. Amplitude scaling of water-gun traces is six times that of air gun.

No evidence in the seismic data exists for lower velocities associated with the deformation zones and faulting determined in cores.

A weak reflector occurs at 1.4 s two-way traveltime, about 1 km below seafloor. A long, high-amplitude downgoing pulse obscures any reflectors occurring at shallower depths.

## MAGNETOMETER LOGS

### Background

Magnetic logging was first attempted during DSDP Legs 68 (Hole 501), 69 (Holes 504B and 505B), and 78B (Hole 395A) by Ponomarev and Nechoroshkov (1983, 1984) using a combination three-component magnetometer and magnetic-susceptibility probe designed and built in the U.S.S.R. The three fluxgate elements of the magnetometer were oriented by gravity in a gimbal suspension system that positioned one of the elements in line with the probe axis, another one horizontal and perpendicular to the direction of inclination of the borehole, and the third perpendicular to the first two and in the plane of inclination of the borehole. The gravitational orientation of the horizontal elements depended on the borehole being somewhat deviated from the vertical, and as the DSDP holes were nearly vertical, the azimuthal orientation was not well controlled and the magnetic declination could not be measured accurately. However, because of the near verticality of the holes, the element in line with the probe axis was positioned appropriately to measure the vertical component, and so it was possible to determine the inclination of the Earth's field; and because the rocks were strongly magnetized, it was possible to determine the inclination of the remanent vector *in situ*. Downhole susceptibility measurements using the combination probe were inaccurate because of temperature problems, and so core susceptibilities were used in their place for interpreting the downhole magnetometer data.

During ODP Leg 102, a three-component magnetometer probe with inclinometer and gyro orientation was provided by the Federal Institute for Geosciences and Natural Resources (BGR) of the Federal Republic of Germany (F.R.G.), and a susceptibility probe was provided by the USGS for logging Hole 418A (Bosum and Scott, 1988). The borehole measurements, which showed a clear reversal in the direction of polarization of the lower basalt section, were interpreted to determine the amplitude and direction of the remanent vector in this interval. The downhole susceptibility measurements were relatively stable because the sensing coil was kept at a nearly constant temperature in a heated chamber near the bottom of the probe. The interpreted results of the downhole magnetic field and susceptibility measurements agreed favorably with those obtained from paleomagnetic laboratory measurements of cores made during DSDP Leg 53 (Levi, 1979).

During ODP Leg 109, magnetometer logs were run in Hole 395A with three different probes (Shipboard Scientific Party, 1988b). One was the same BGR probe used during Leg 102, another was an unoriented, high-temperature, three-component magnetometer probe of Japanese design, and the third was the unoriented, three-component magnetometer in the Schlumberger General Purpose Inclinometer Capsule (GPIC) that was run with the Schlumberger Litho-Density Tool (LDT). The Japanese magnetometer logs were interpreted to determine the total field, vertical and horizontal components, and inclination. Although the BGR probe was equipped with inclinometers and a gyro for orientation, this system was not completely operational during Leg 109 because the lower assembly of the probe broke off and was lost in the hole. Therefore, only the vertical component of the Earth's field was recorded. The Schlumberger magnetometer, though relatively insensitive, was used to record the three measured components and the total field. An experimental three-coil magnetic-susceptibility probe developed by the Institute of Applied Geophysics (University of Munich, F.R.G.) was also run successfully during Leg 109.

During Leg 111, the same Japanese and Schlumberger three-component magnetometer probes were run in Hole 504B. Unfortunately, the rechargeable battery power supply of the Japanese probe shorted out, causing the batteries to explode, which made data retrieval impossible. Although the sensitivity of the Schlumberger magnetometer was fairly low, the log revealed two features very clearly: (1) a change of *in-situ* inclination between pillow basalts and the sheeted dike complex and (2) abrupt changes in remanent magnetic intensity between the pillow basalts and pillow-dike transition and between the sheeted dike complex (Shipboard Scientific Party, 1988a).

### Leg 118 Magnetic Logging Equipment

During Leg 118, downhole magnetic measurements were performed with the same USGS susceptibility probe used during Leg 102: a USGS three-component magnetometer probe similar to the BGR probe with gyro and inclinometer orientation, and a combination three-component magnetometer and susceptibility probe developed by the University of Washington (UW) in coordination with the Lamont-Doherty Borehole Research Group. The unoriented magnetometer in the Schlumberger GPIC capsule was also run in conjunction with the Schlumberger LDT tool. The magnetic logging tools run during Leg 118 are described in detail in the following paragraphs.

The USGS magnetic-susceptibility probe contains a solenoid sensing coil connected in the measuring arm of a Maxwell

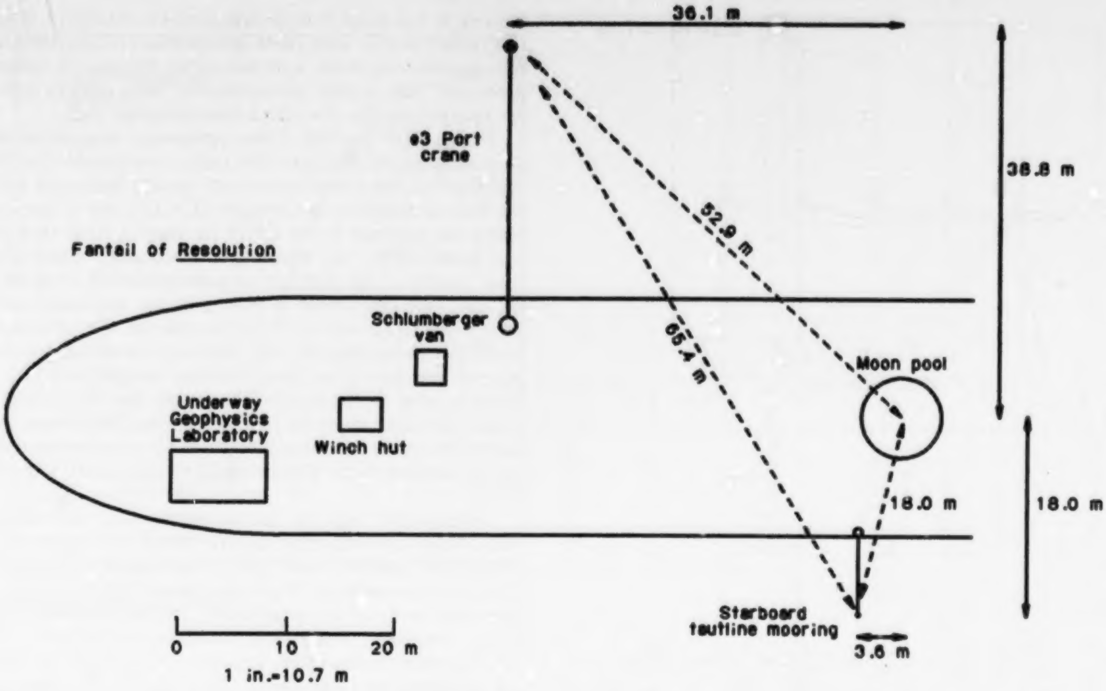

Figure 94. Scaled layout of VSP showing relative positions of receiver (center of moon pool), sources (outboard end of number 3 port aft crane), and source monitor (starboard tautline mooring).

**Table 13. Amplitude ratio between connectors.**

| Frequency (Hz) | Vertical (1/5) high imp. | Horiz. 1 (2/5) high imp. | Horiz. 2 (3/5) high imp. | Vertical (1/5) 50-ohm imp. | H1/H2 (2/3) high imp. |
|---|---|---|---|---|---|
| 10 | 1.00 | 0.99 | 0.99 | 1.08 | — |
| 20 | 1.00 | 0.99 | 1.00 | 1.08 | 0.00075 |
| 50 | 1.00 | 0.99 | 0.98 | 1.07 | 0.00083 |
| 100 | 1.00 | 0.99 | 1.00 | 1.00 | 0.00084 |
| 200 | 1.00 | 0.98 | 0.98 | 0.80 | 0.001 |
| 500 | 0.92 | 0.89 | 0.90 | 0.38 | 0.010 |
| 1,000 | 0.71 | 0.71 | 0.69 | 0.22 | 0.028 |
| 2,000 | 0.43 | 0.39 | 0.40 | 0.13 | 0.056 |
| 5,000 | 0.21 | 0.20 | 0.19 | 0.06 | 0.064 |
| 10,000 | 0.16 | 0.16 | 0.16 | 0.06 | 0.080 |
| 20,000 | — | — | — | 0.02 | 0.070 |

bridge, which is nulled in a zero-susceptibility environment (air) prior to logging (Scott et al., 1981). The sensing coil is contained in a thermally insulated chamber where the temperature is held nearly constant (at 82°C) to minimize drift. The off-null signal from the bridge is sent up the logging cable along with a reference signal from the 1000-Hz oscillator (both in analog form) to the surface module, where a phase detector is used to separate the susceptibility component from the conductivity component. The amplitude of the susceptibility signal is a nearly linear function of the susceptibility of rock near the borehole in the range 0–20,000 × $10^{-6}$ cgs. The conductivity signal is useful only for detecting concentrations of highly conductive minerals such as graphite and metallic sulfides because at the operating frequency of 1000 Hz, the bridge is relatively insensitive to changes in resistivity above 0.1 ohm-m, although it is quite sensitive to susceptibility at this frequency. A block diagram of the USGS borehole magnetic-susceptibility system is shown in Figure 101. A Hewlett-Packard HP-9845B desktop computer was used to control data acquisition; digitization was accomplished by an HP-3455A DVM. Data were recorded by an HP-9875A digital magnetic tape unit. The depth of the probe was obtained from the ship's wireline winch system, which was monitored by the MassComp computer in the Downhole Measurements Laboratory and transferred to the HP-9845B computer via an RS-232 cable link. During logging, weight sections were added to the bottom of the probe, which made the total weight 143 kg and total length 8 m.

The USGS three-component magnetometer probe is shown schematically in Figure 102 (Scott and Olson, 1985). The probe's gyroscopic azimuthal reference is read to the nearest 0.1° from 0–358° (with a dead band from 358° to 360°), and must be corrected for drift, which usually is 1° or 2°/hr. Gyro drift is assumed to be linear with time, and time is recorded to the nearest second when each probe reading is taken. Azimuthal reference readings are made with the *X*-axis of the probe oriented in a known direction before and after logging by means of a telescopic sight that is temporarily attached to the top of the probe for that purpose. A gyro drift correction is computed for each probe reading from the azimuthal sightings made before and after the logging run and from the time recorded for each reading. The probe contains two inclinometers aligned with the probe's horizontal *X*- and *Y*-axes that are used to measure the tilt of the probe to 0.01°. The three orthogonally oriented fluxgate magnetometer elements measure the Earth's magnetic field to a resolution of 10 nT. The internal temperature of the probe is measured to 0.1°C and is used to correct the inclinometer and magnetometer readings for temperature effects. The offset voltage of the downhole power supply is also monitored while the other measurements are being conducted. These eight parameters are digitized downhole and sent up the cable as a pulse-coded FM signal that is decoded by a surface control module. The control module is connected to the Hewlett-Packard 9845B desktop

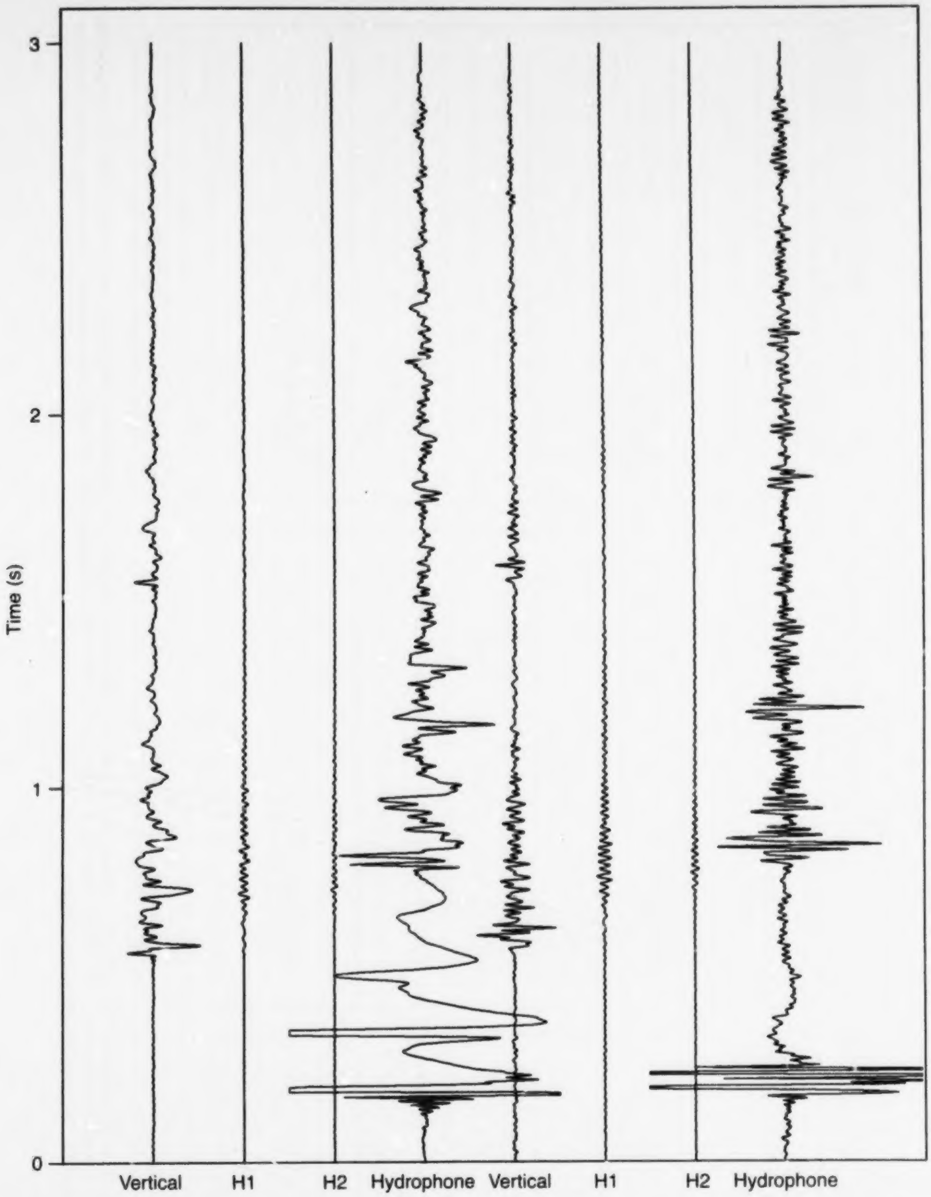

Figure 95. Examples of stacked seismograms. Four channels shown for air gun (left) and water gun (right). Receiver at 489 mbsf. True amplitude scaling with amplitude of water-gun traces scaled up by about twice that of air-gun traces. Passband filtered at 5 to 80 Hz. Highest peaks in the first 0.3 s on hydrophone traces were clipped intentionally to improve clarity of display.

computer by an RS-232 interface cable. The computer is used to control the acquisition of borehole data and to record all of the downhole measurement parameters, along with time and depth information obtained from computer peripherals (clock and depth modules). Depth values are obtained via an RS-232 link to the MassComp computer, which is used to monitor the ship's wireline winch measurement system. Depth, time, and probe readings are transferred by a Hewlitt-Packard IB interface cable to an HP-9875A tape deck that records them on digital tape. During logging, centralizer springs and weight sections were attached to the top and bottom of the probe, increasing the total weight to 206 kg and length to 12 m.

The UW combination magnetometer-susceptibility tool was recently developed in conjunction with the Lamont-Doherty Borehole Research Group for routine use during ODP legs that include downhole logging measurements. A large portion of the probe was designed by IFG Corporation of Toronto, Canada, which made several modifications to the basic design of the probe specifically for ODP logging. The tool contains three orthogonally oriented ring-core fluxgate magnetometers and a susceptibility coil and can operate at temperatures up to 125°C. Although the tool is not oriented azimuthally at the present time, this is a feature that will be included eventually. Data are digitized downhole, and a total of eight parameters can be mon-

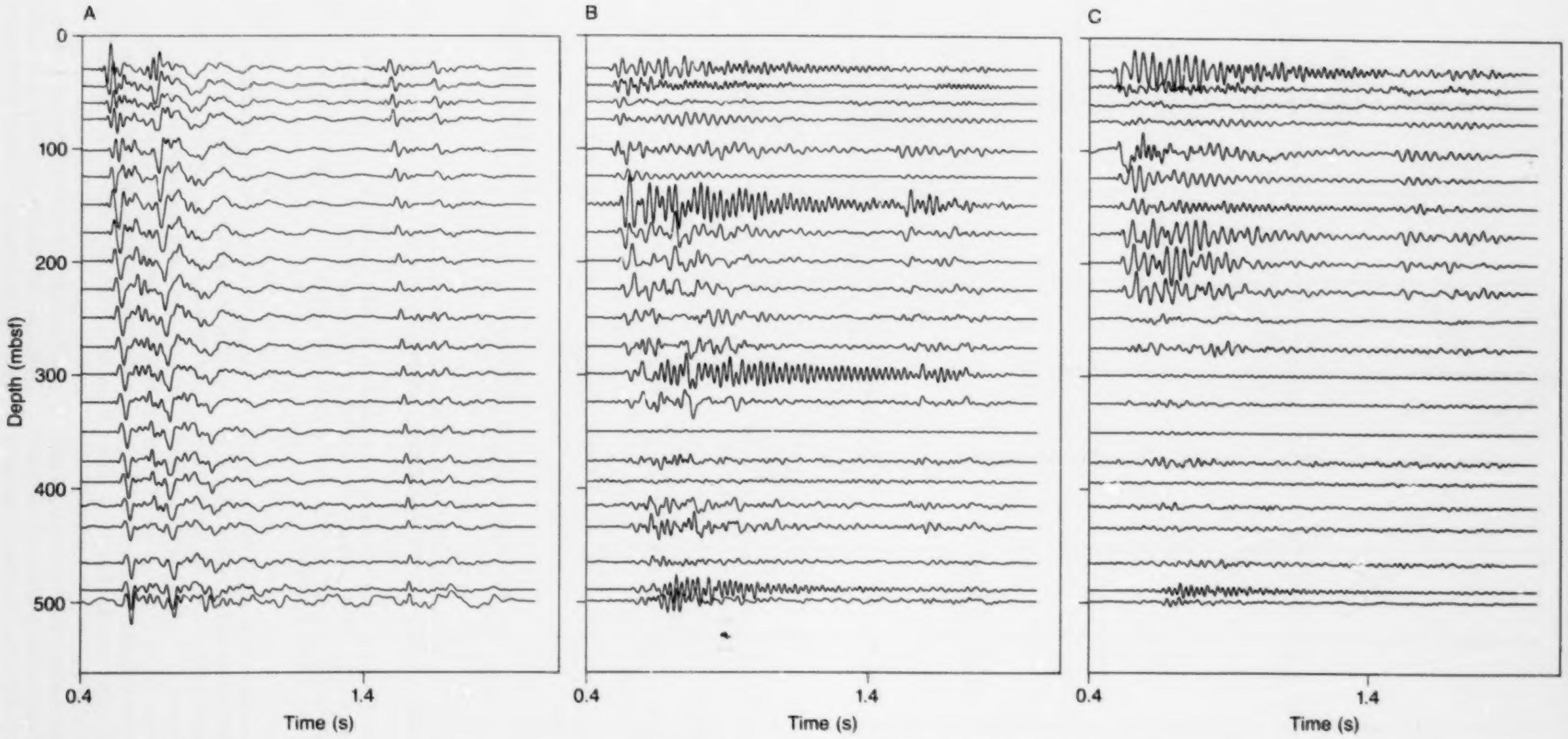

Figure 96. Stacked air-gun seismograms plotted vs. receiver depth below seafloor. Vertical (A), horizontal 1 (B), and horizontal 2 (C) channels. Passband filtered at 5 to 50 Hz. True amplitude scaling. Vertical channel: all seismograms scaled the same; horizontal 1: 3.3X vertical channel at 0–80 mbsf and 12X vertical channel at 80–500 mbsf; horizontal 2: 3.3X vertical channel at 0–80 m and 36X vertical channel at 80–500 mbsf. Azimuth of H1 and H2 varies with depth.

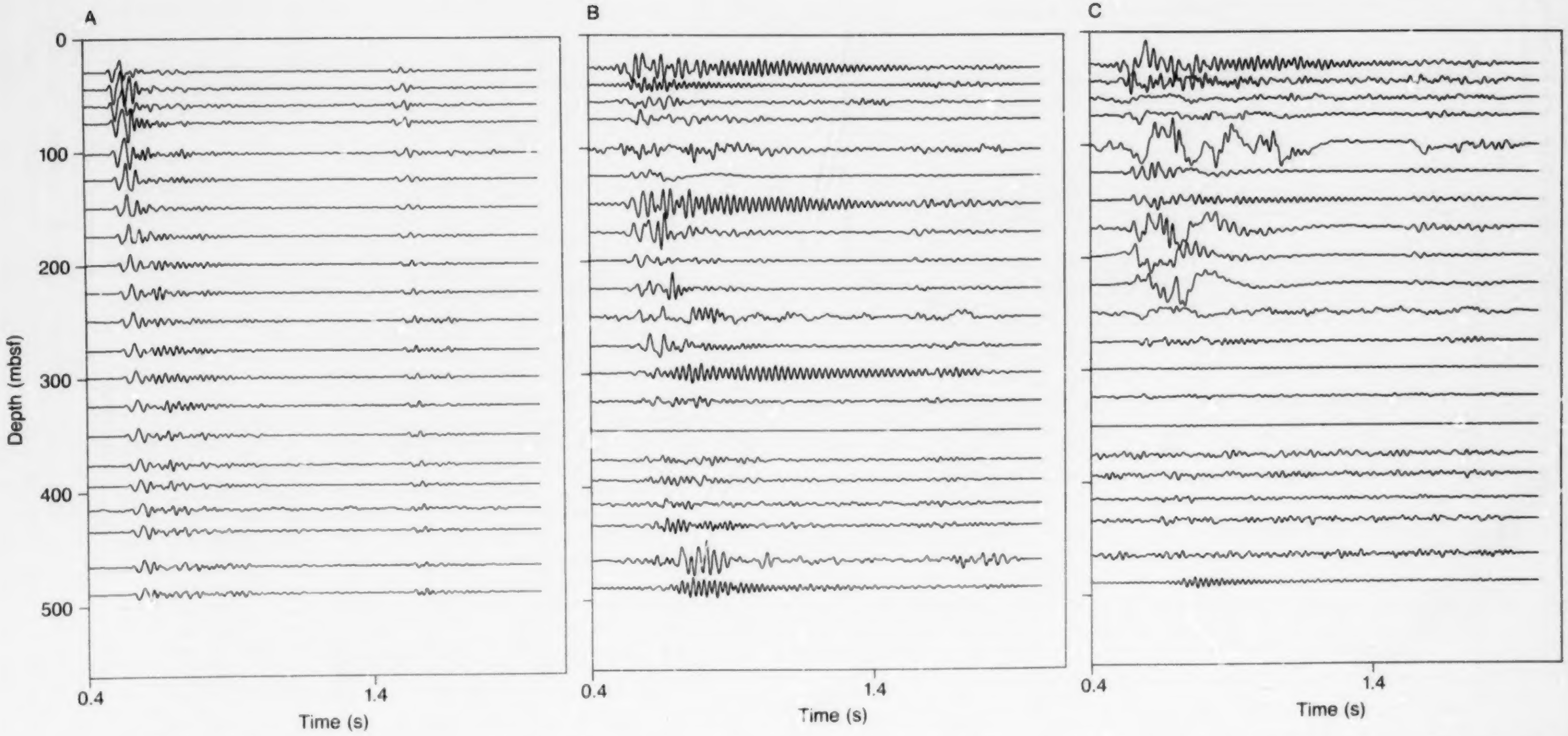

Figure 97. Stacked water-gun seismograms plotted vs. receiver depth below seafloor. Vertical (A), horizontal 1 (B), and horizontal 2 (C) channels. Passband filtered at 5 to 50 Hz. True amplitude scaling. Vertical channel: all seismograms scaled the same; horizontal 1: 3X vertical channel at 0–80 mbsf and 10X vertical channel at 80–500 mbsf; Horizontal 2: 3X vertical channel at 0–80 mbsf and 30X vertical channel at 80–500 mbsf. Azimuth of H1 and H2 varies with depth.

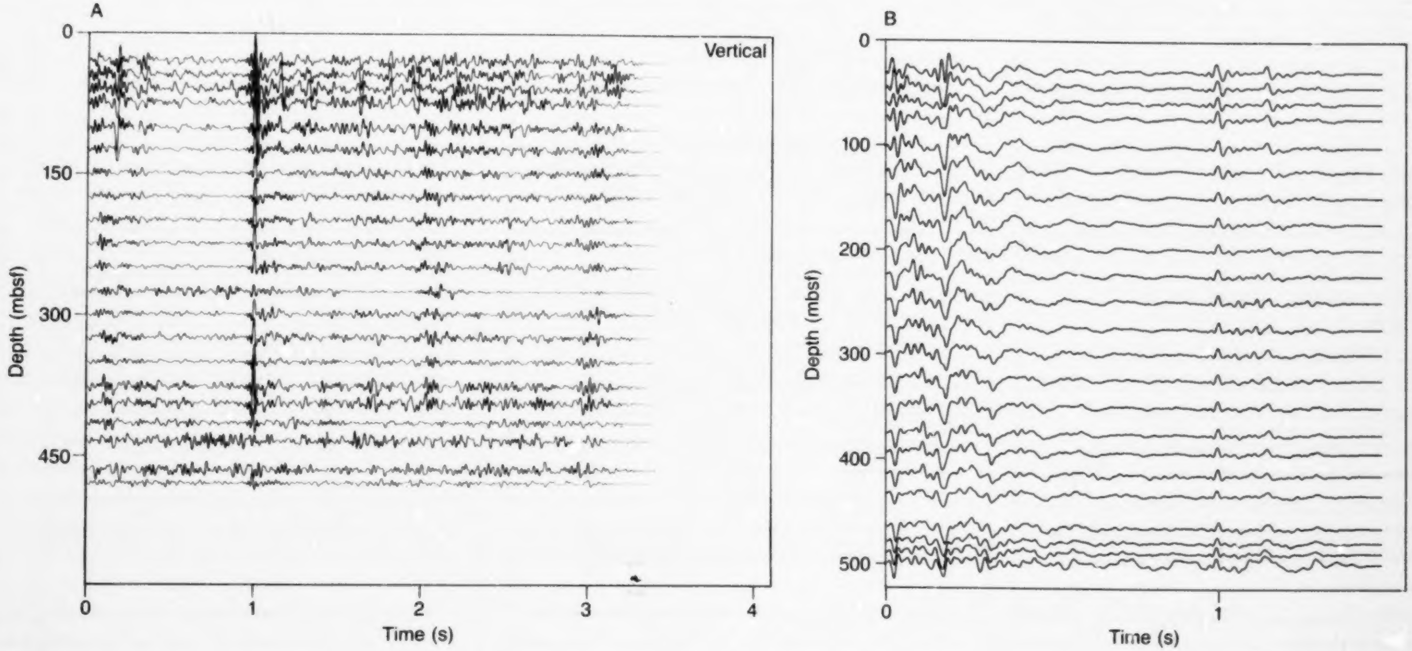

Figure 98. Air-gun (vertical channel) seismograms. Traces have been shifted to earlier time by subtracting the first arrival time. A. True amplitude scaling. Passband filtered at 5 to 50 Hz. B. Automatic gain control using a window of 0.5 s. Deconvolved with a Burg filter 0.2 s long.

**Table 14. First compressional-wave arrival time selected from seismograms recorded using the WHOI three-component seismometer.**

| | Air gun | | Water gun | |
|---|---|---|---|---|
| Receiver depth (mbsf) | Number of shots in stack | Arrival time (s) | Number of shots in stack | Arrival time (s) |
| 29 | 6 | 0.482 | 6 | 0.482 |
| 44 | 5 | 0.485 | 6 | 0.485 |
| 59 | 7 | 0.489 | 5 | 0.489 |
| 74 | 6 | 0.491 | 6 | 0.492 |
| 101 | 8 | 0.495 | 6 | 0.496 |
| 124 | 6 | 0.499 | 6 | 0.501 |
| 149 | 6 | 0.503 | 3 | 0.503 |
| 174 | 7 | 0.507 | 5 | 0.508 |
| 199 | 6 | 0.509 | 8 | 0.511 |
| 224 | 8 | 0.515 | 5 | 0.515 |
| 249 | 6 | 0.518 | 6 | 0.518 |
| 275 | 6 | 0.521 | 6 | 0.522 |
| 299 | 7 | 0.526 | 5 | 0.526 |
| 324 | 4 | 0.530 | 5 | 0.530 |
| 350 | 7 | 0.534 | 4 | 0.534 |
| 376 | 6 | 0.537 | 6 | 0.538 |
| 394 | 11 | 0.541 | 5 | 0.538 |
| 415 | 4 | 0.545 | 5 | 0.545 |
| 434 | 6 | 0.548 | 5 | 0.547 |
| 465 | 9 | 0.549 | 4 | 0.552 |
| 479 | 5 | 0.553 | 4 | 0.602 |
| 489 | 11 | 0.552 | 4 | — |
| 499 | 7 | 0.554 | — | — |

**Table 15. First compressional-wave arrival time selected from seismograms recorded using the Schlumberger vertical-component seismometer.**

| | Air gun | | Water gun | |
|---|---|---|---|---|
| Receiver depth (mbsf) | Number of shots in stack | Arrival time (s) | Number of shots in stack | Arrival time (s) |
| 29 | 5 | 0.483 | — | — |
| 39 | 6 | 0.485 | 4 | 0.488 |
| 59 | 7 | 0.488 | 6 | — |
| 70 | 5 | — | 6 | — |
| 99 | 5 | — | 5 | — |
| 115 | 6 | 0.497 | 5 | 0.468? |
| 119 | 7 | — | 7 | — |
| 139 | 5 | 0.301? | 6 | 0.505 |
| 151 | — | — | 5 | — |
| 159 | — | — | — | — |
| 160 | 5 | — | | |
| 179 | 5 | — | 5 | 0.508 |
| 199 | 5 | 0.511 | 5 | — |
| 214 | 6 | 0.513 | 5 | 0.515 |
| 219 | 5 | 0.514 | 5 | — |
| 239 | 4 | 0.515 | 2 | 0.671? |
| 259 | 5 | 0.520 | 5 | — |
| 279 | 5 | 0.524 | 5 | 0.527 |
| 299 | 5 | 0.527 | 5 | — |
| 319 | 5 | 0.527 | 5 | — |
| 320 | 6 | 0.530 | 5 | 0.530 |
| 339 | 6 | 0.533 | 5 | — |
| 359 | 5 | — | 5 | 0.538 |
| 379 | — | — | 6 | — |
| 390 | 5 | 0.540 | 6 | 0.440? |
| 415 | 5 | — | 5 | 0.545 |
| 428 | 5 | — | 5 | — |
| 450 | 5 | — | 5 | 0.550 |
| 466 | 6 | — | 1 | — |
| 491 | 5 | — | 4 | — |

itored on the surface. These include the *X*, *Y*, and *Z* components of the magnetic field, total magnetic intensity, magnetic susceptibility, internal voltage, the temperature of the electronics section, and the temperature of the magnetometer section.

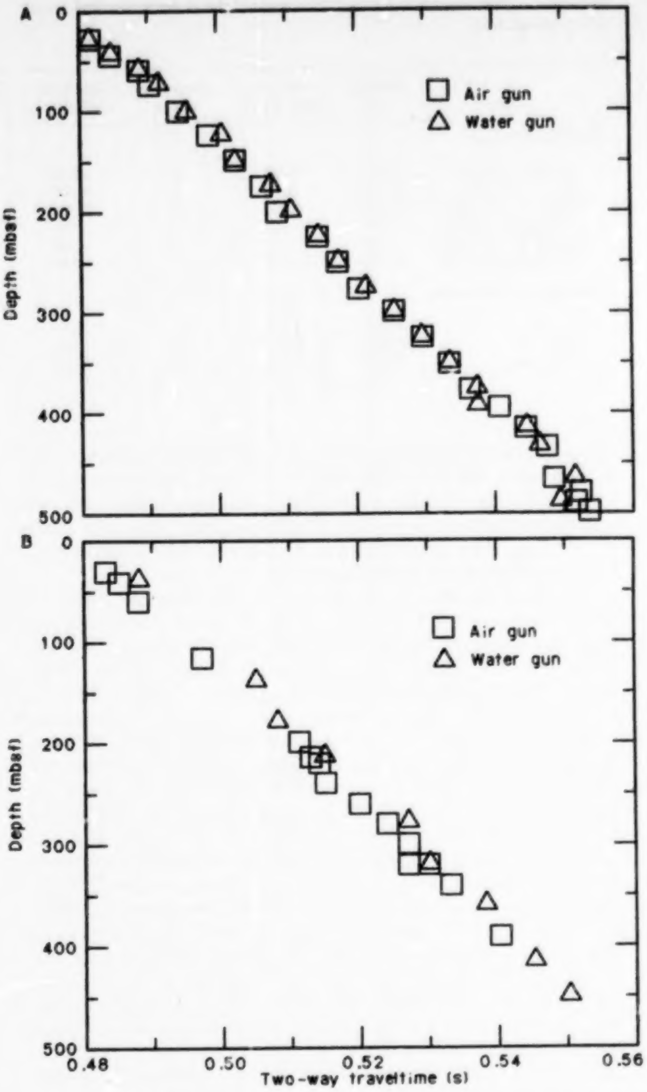

Figure 99. Plot of two-way traveltime of first compressional arrival selected from stacked seismograms vs. depth below seafloor. A. WHOI three-component seismometer. B. Schlumberger vertical-component seismometer.

## Logging Data

The susceptibility log obtained with the USGS tool was made by logging uphole at a speed of 9 m/min after allowing the probe to approach thermal stability at the bottom for about 30 min. Data reduction included applying a correction for hole diameter and applying a five-point smoothing filter. Results indicate that the susceptibility of gabbro in the the upper 200-m section of the hole is extremely variable, with one thin zone approaching 7000 × $10^{-6}$ cgs and many thin anomalies peaking out between 1000 and 2000 × $10^{-6}$ cgs, but with many other values approaching zero (Fig. 103). Midway down the hole, a 60-m zone of high susceptibility (2000–4000 × $10^{-6}$ cgs) occurs in a gabbroic section containing anomalously high concentrations of magnetite and ilmenite. Below the magnetite-ilmenite-

**Table 16. Linear regression fits of first arrival times from vertical channel seismograms.**

| Data | Intercept (s) | Inverse slope (km/s) | Number of points | Regression coefficient (r) |
|---|---|---|---|---|
| WHOI Seismometer | | | | |
| Air gun, all depths | 0.4796 | 6.530 | 23 | 0.9987 |
| Air gun, 0–435 m | 0.4788 | 6.327 | 19 | 0.9993 |
| Water gun, all depths | 0.4798 | 6.459 | 20 | 0.9987 |
| Water gun, 0–435 m | 0.4798 | 6.467 | 19 | 0.9984 |
| Both guns, all depths | 0.4797 | — | 43 | 0.9986 |
| Both guns, 0–435 m | 0.4793 | 6.396 | 38 | 0.9988 |
| Schlumberger Seismometer | | | | |
| Air gun | 0.4788 | 6.321 | 15 | 0.9987 |
| Water gun | 0.4827 | 6.617 | 9 | 0.9981 |
| Both guns | 0.4799 | 6.384 | 24 | 0.9968 |

rich gabbros a magnetically quiet zone 100 m thick occurs, with susceptibility averaging 200-300 × $10^{-6}$ cgs. Below this zone another highly variable 100-m-thick interval occurs near the bottom of the hole, with susceptibilities in the range 200–3000 × $10^{-6}$ cgs. This interval is also characterized by high magnetite and ilmenite concentrations in the drill cores.

The logs obtained with the USGS magnetometer tool are shown in Figures 104 and 105. Logs of probe orientation vs. depth are shown in Figures 104A and 104B. In Figure 104A the azimuth of the probe (direction that the bottom of the probe points toward) is referenced to the gyro, and in Figure 104B, it is referenced to the magnetometer. In both cases, 0° represents magnetic north and ± 180° represents magnetic south. The log in Figure 104A is referenced to magnetic north at sea level, and the log in Figure 104B is referenced to local magnetic north, as measured in the borehole by the magnetometer in the probe. Local magnetic north varies throughout the hole in the sections containing strongly magnetized rocks. An example of this variability can be seen in Figure 104B in the depth interval 230-280 mbsf, where the azimuth referenced to the magnetometer deviates as much as 90° from the azimuth referenced to the gyro in Figure 104A. Figure 104C shows the tilt of the probe (and the borehole) with respect to the vertical. Near the top of the hole, the tilt is about 6° and the hole points about 30° east of magnetic north (almost directly toward true north because the magnetic declination is 32° west at the site). The bottom of the hole tilts about 4° from the vertical and points toward magnetic east (equivalent to N60°E with respect to true north).

Figure 106 shows the direction and magnitude of the magnetic vector representing the Earth's field, as measured in Hole 735B. Figure 105A gives the azimuthal direction of the horizontal component of the Earth's field referenced to magnetic north at sea level above the hole. Figure 106B shows the inclination of the field in the borehole, and Figure 106C gives the total field. The iron-titanium oxide-rich zones midway down the hole and near the bottom of the hole show up on all three logs as strongly anomalous intervals having magnetic polarizations approximately opposite to the direction of Earth's present field.

The UW magnetometer-susceptibility tool was run for the first time in Hole 735B. The hole was logged at two different speeds, going uphole and downhole, to check repeatability. The overall performance of the tool was good, although there appears to have been a problem with the initial zeroing and calibration of the susceptibility coil. Unfortunately, the short time interval between logging and the termination of Leg 118 did not allow for a thorough examination of this problem.

Data from the uphole log are displayed in Figure 106. Although the magnetometer log agrees well with that of the USGS tool, the susceptibility appears to be very noisy, which is probably a result of the aforementioned problems. The most salient features of the magnetic field data are the abrupt increases in signal amplitude that occur within the magnetite-ilmenite-rich gabbros between 224 and 272 mbsf and below 405 mbsf. Between the magnetite- and ilmenite-rich zones, the signal amplitude is low and has only intermittent, narrow zones of high field intensity. Further interpretation of the logging data will occur when the contribution of the Earth's magnetic field can be removed accurately and the contribution of remanent magnetization of the surrounding rock has been examined independently.

Vertical magnetic field measurements in Hole 735B from the Schlumberger, USGS, and UW magnetometers are compared in Figure 107. Although sampling density and sensitivity are different in each tool, the overall character of the logs agrees well. All three logs show an abrupt increase in vertical magnetic field between 224 and 272 mbsf and below 405 mbsf, which correlates with the presence of magnetite-ilmenite-rich gabbro. In addition, the quietest part of each log occurs from 272 to 405 m within lithologic Unit V, which consists of olivine with a distinct absence of magnetite-ilmenite-rich zones.

## Summary of Magnetic Measurements of Cores, Hole 735B

Results of shipboard laboratory measurements of minicores from Hole 735A (see "Paleomagnetics" section, this chapter) indicated that the gabbroic rocks have the following approximate magnetic properties before demagnetization.

| | Average | Range |
|---|---|---|
| Susceptibility: | 500 × $10^{-6}$ cgs | 20-10,500 × $10^{-6}$ cgs |
| Intensity of remanent magnetization: | 1000 × $10^{-6}$ emu/cm$^3$ | 5-100,000 × $10^{-6}$ emu/cm$^3$ |
| Inclination: | 65° | −80° to 80° |

The extreme variability and broad range of the magnetic properties of rocks penetrated by the borehole are indicated by both the laboratory and the downhole magnetic measurements. However, the borehole measurements indicate that the entire section is reversely polarized *in situ*, suggesting that the negative NRM inclinations measured in the laboratory were induced by drilling, or perhaps by pulling the core through the pipe (730-1230 mbrf) during wireline core recovery. In any case, the normal component is soft and easily removed by AF demagnetization.

## Geomagnetic Field at Site 735

The total force of the geomagnetic field at Site 735 was measured by the ship's towed magnetometer system during a site survey just before drilling began and again just after the ship left the site. The vertical component was computed from the total force and the inclination. Inclination and declination of the Earth's field were estimated for Site 735 from published IGRF charts (IGRF, 1980).

| | |
|---|---|
| Total force: | 37,250 nT (± 50) |
| Vertical component: | 32,259 nT |
| Inclination: | −60° (up) |
| Declination: | 32°W |

These values will be used for the final interpretation of downhole magnetic measurements with the objective of estimating the direction and intensity of the remanent vector *in situ*. If this is successful, it should be possible to determine the azimuthal orientation of the cores for which the direction of the remanent

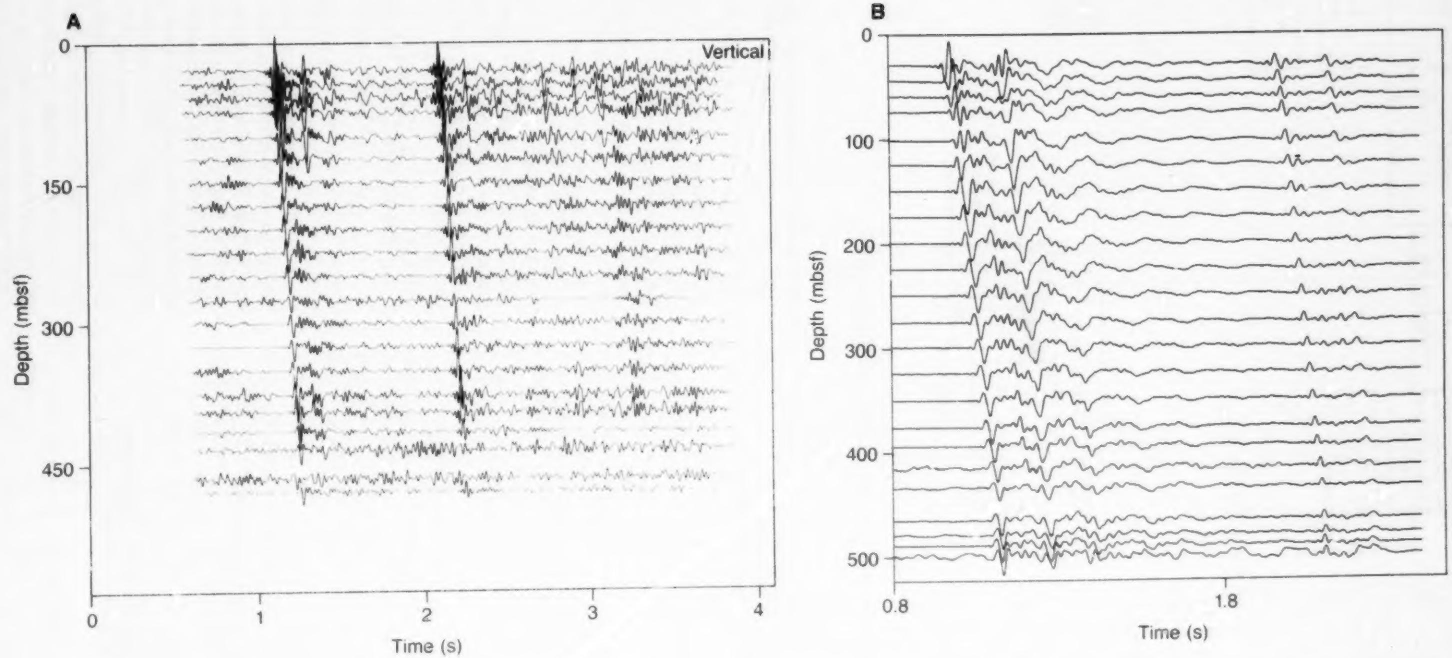

Figure 100. Stacked seismograms shot with air-gun source and plotted vs. receiver depth below seafloor. Traces are offset to later time by the one-way traveltime. A. True amplitude scaling. B. Automatic gain control and deconvolution as in Figure 98B.

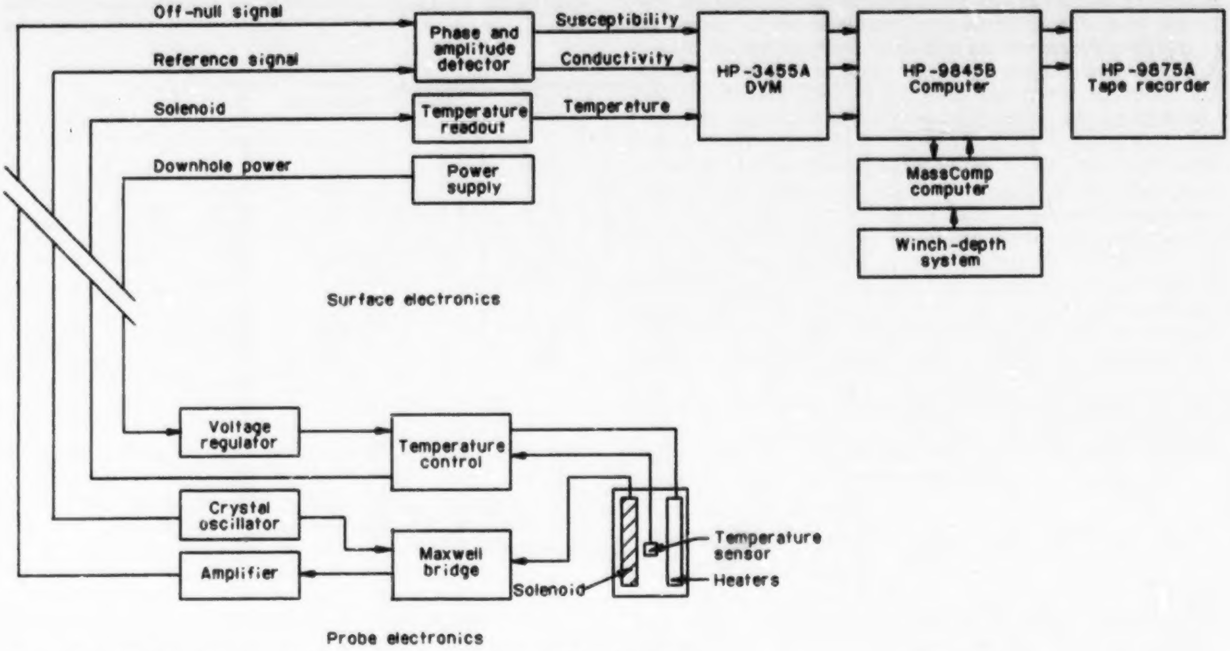
Off-null signal
Reference signal
Solenoid
Downhole power
Phase and amplitude detector
Temperature readout
Power supply
Susceptibility
Conductivity
Temperature
HP-3455A DVM
HP-9845B Computer
HP-9875A Tape recorder
MassComp computer
Winch-depth system
Surface electronics
Voltage regulator
Temperature control
Crystal oscillator
Amplifier
Maxwell bridge
Solenoid
Temperature sensor
Heaters
Probe electronics

Figure 101. Block diagram of the USGS magnetic-susceptibility well logging system.

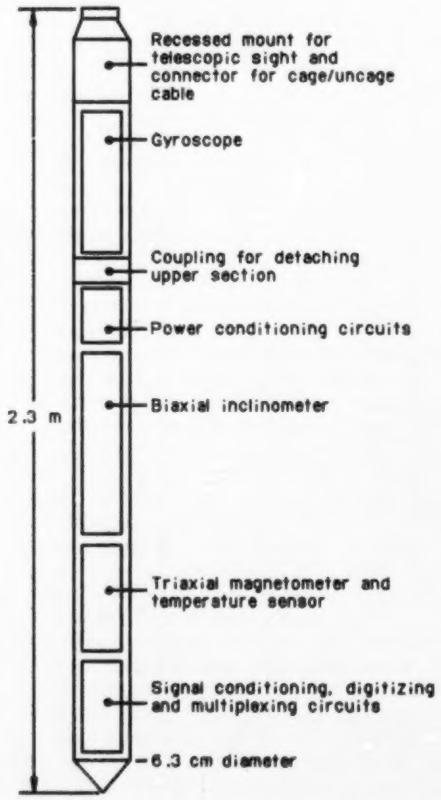
Recessed mount for telescopic sight and connector for cage/uncage cable
Gyroscope
Coupling for detaching upper section
Power conditioning circuits
2.3 m
Biaxial inclinometer
Triaxial magnetometer and temperature sensor
Signal conditioning, digitizing and multiplexing circuits
6.3 cm diameter

Figure 102. Diagram of the USGS three-component magnetometer probe (not to scale).

vector has been determined after AF demagnetization has stripped off the soft induced normal polarization.

### Conclusions

The success of magnetic logging conducted during Leg 118 will contribute significantly to our overall understanding of the vertical magnetic structure of the crustal section penetrated by Hole 735B. The *in-situ* logging measurements will be used together with laboratory measurements of discrete samples to provide an integrated interpretation of the paleomagnetic character of gabbro at Site 735. In particular, logging data will be very important in constraining the *in-situ* magnetic directions and intensities of the ilmenite-magnetite-rich gabbros. Future interpretation of magnetic data will draw heavily on the petrographic and geochemical data that are obtained from the drill core of Hole 735B.

## PERMEABILITY MEASUREMENTS IN THE GABBROS OF HOLE 735B

### Introduction

The circulation of seawater and pore fluids through the oceanic crust plays a vital role in the development of the physical and chemical nature of the crust. The modes and effects of circulation are largely controlled by the variable permeability and porosity of the basaltic and gabbroic formations that constitute the oceanic crust. As crustal permeability and porosity probably vary with irregular fractures and voids of unknown scale, they cannot be reliably determined from dredged or cored samples. Instead, bulk permeability and porosity must be measured *in situ*, at averaging scales large enough to include the effects of irregular fracture porosity and to avoid the disturbance of drilling on the formation.

There are several downhole logs and experiments with which porosity can be estimated (e.g., "Schlumberger Logs" section, this chapter). However, while it is intuitive that there must be

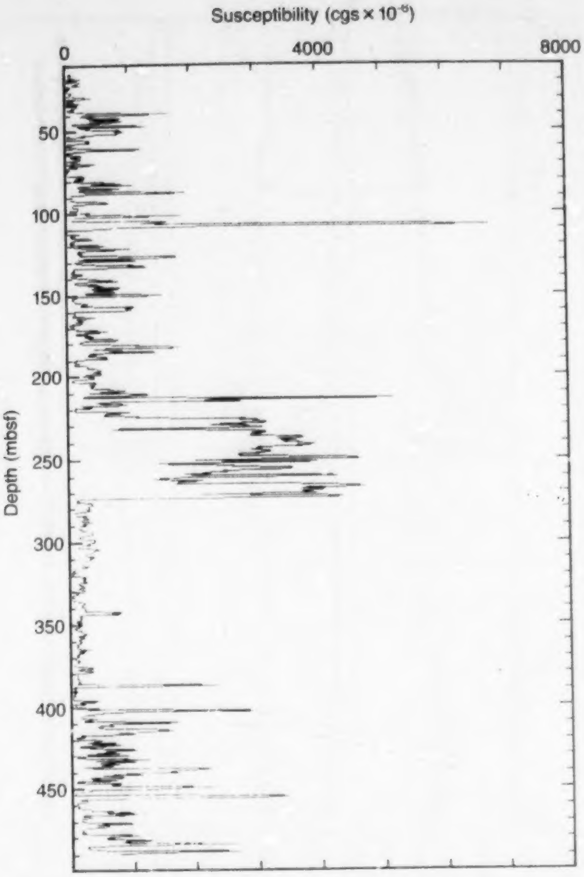

Figure 103. Magnetic susceptibility log of Hole 735B made with the USGS susceptibility tool. Hole diameter correction and 5-point smoothing filter (1-m span) applied.

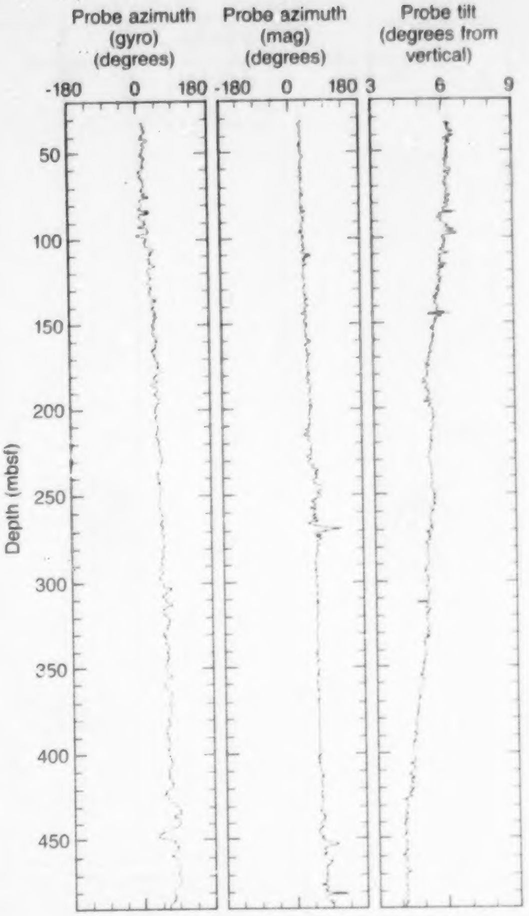

Figure 104. Magnetometer-derived logs of probe orientation in Hole 735B. A. Probe azimuth referenced by the gyro to magnetic north at sea level directly above Hole 735B. B. Probe azimuth referenced by the magnetometer to local magnetic north in the borehole. C. Probe tilt computed from the biaxial inclinometers. A 5-point smoothing filter (1.5-m span) was applied to all th[illegible]anels.

some relationship between permeability and porosity, the permeability of the oceanic crust cannot be reliably determined from its porosity. Many scales of crustal porosity occur, among them intergranular or pore porosity, cracks, and large fractures, not all of which contribute to permeability. The permeability of the oceanic crust is probably dominated by large-scale, interconnected porosity, which cannot be unequivocally distinguished from other forms of porosity by logging.

To date, the only reliable means of assessing crustal permeability is by actively testing the formation *in situ*, which is usually done using a packer to isolate a section of a borehole that penetrates the formation. Before Leg 118, drill-string packers had been deployed several times during DSDP and ODP cruises, but only Holes 395A and 504B were the rare holes that penetrate deeply into the oceanic crust. The permeability of the pillow lavas and sheeted dikes in Hole 504B was measured during Legs 69, 70, 83, and 111 by Anderson and Zoback (1982), Becker et al. (1983), Anderson et al. (1985), and Becker (unpubl. data), respectively. The permeability of the pillow lavas cored in Hole 395A was measured during Leg 78B by Hickman et al. (1984) and during Leg 109 by Becker (unpubl. data).

The permeability of oceanic gabbros has never before been measured *in situ*. Thus, Hole 735B presented an outstanding opportunity to significantly augment our knowledge about the permeability of the oceanic crust, even though the tectonized gabbros cored in the hole d[illegible]present "normal" oceanic layer 3. During the la[illegible]e trip of Leg 118, a drill-string packer was set six times in Hole 735B to measure the bulk permeability of several zones of the gabbroic formations cored (listed in the order that the measurements were performed):

1. From 49 mbsf to the bottom of the hole at 500.7 mbsf, encompassing lithologic Units II through VI.
2. From 47 mbsf to hole bottom (a reset to check the packer performance).
3. From 389 mbsf to hole bottom, Unit VI.
4. From 299 mbsf to hole bottom, Units V and VI.
5. From 223 mbsf to hole bottom, Units IV, V, and VI.
6. From 223 mbsf to hole bottom (a reset to verify the important result from the previous set).

The depths at which the packer was set were chosen primarily on the basis of logging results, particularly resistivity, density, and borehole televiewer measurements, which clearly distinguished the deepest five of the six major lithologic units (see "Lithostratigraphy" section, this chapter).

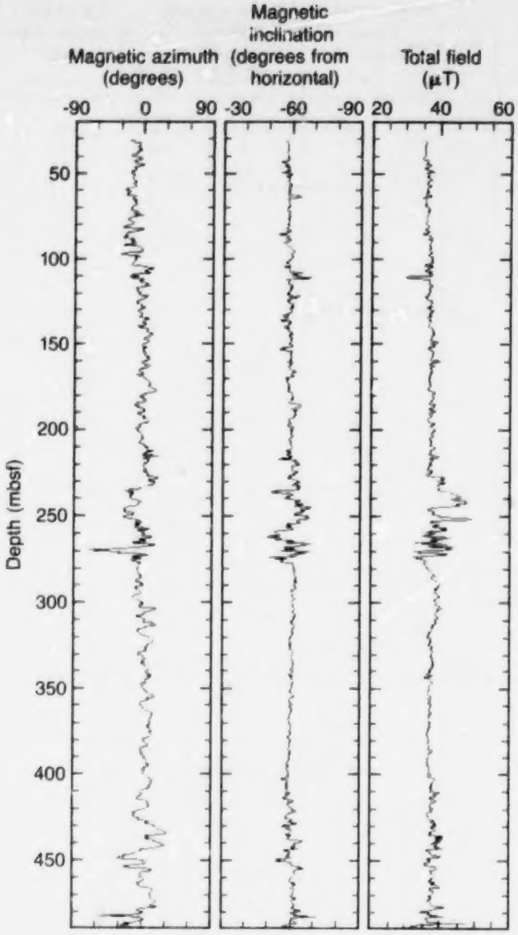

Figure 105. Magnetometer-derived logs of magnetic vector parameters in Hole 735B. A. Magnetic azimuth referenced by the gyro to magnetic north at sealevel. Magnetic north, east and west are 0°, 90°, and −90°, respectively. B. Magnetic inclination computed from the gyro inclinometer-referenced magnetometer measurements. C. Total field in microTeslas (T × $10^{-6}$) computed as the vector sum of the three-axis magnetometer measurements. A 5-point smoothing filter (1.5-m span) was applied to all three panels.

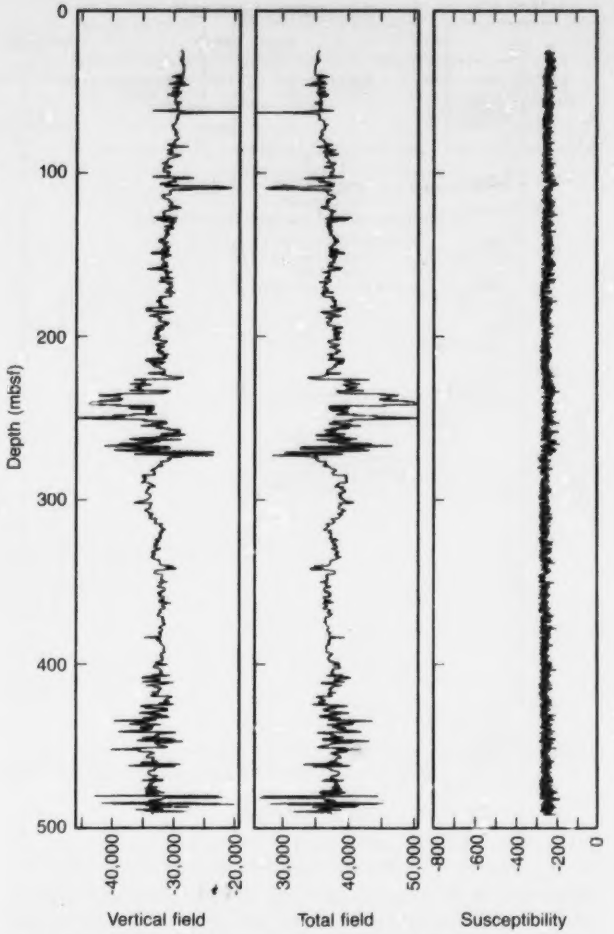

Figure 106. UW magnetometer measurements made within Hole 735B. Vertical magnetic and total magnetic field are in nannoTeslas. Susceptiblity is plotted on relative scale.

Because these measurements were performed when only three days of Leg 118 remained, none of the data could be analyzed. Here, we first review the measurement of permeability using a packer and then describe the operational procedures followed for the measurements performed in Hole 735B. We present only the basic downhole pressure data and can only briefly discuss a few preliminary, qualitative inferences that can be drawn about the permeability of the gabbros in Hole 735B from the character of these data.

## Experimental Procedures

### *Permeability Measurements Using Drill-String Packers*

A packer can be defined as a device that produces a hydraulic seal in a borehole (Fig. 108). If the integrity of this hydraulic seal is properly maintained, the hydrologic properties of the formation can be tested by applying differential fluid pressures to the isolated section. Formation properties that can be measured using a packer include pore pressure, transmissivity (from which permeability can be derived), and storage coefficient (which is closely related to bulk formation porosity). During Leg 118, these properties were tested using two types of experiments:

1. Pulse or "slug" tests, in which downhole pressure recorders monitor the decay of short, effectively instantaneous pressure pulses applied to the formation using the surface pumps. In a relatively impermeable formation, the period of decay of such a pulse will be long compared to the duration of the pulse, and the permeability can be determined using the theory for an instantaneous pulse (Cooper et al., 1967; Papadopulos et al., 1973; Bredehoeft and Papadopulos, 1980). In a permeable formation, a pressure pulse will decay rapidly, and injection tests must be run.
2. Constant-rate injection tests, in which downhole pressure recorders monitor the approach of downhole pressure to a nearly steady-state value as fluid is pumped into the isolated formation at a constant rate. The permeability can be estimated from the rise of downhole pressure using a form of Darcy's Law (e.g., Matthews and Russell, 1967).

During Leg 118, we used a drill-string packer made by TAM International of Houston and described by Becker (1986). This is a nonrotatable packer that is installed in the bottom-hole as-

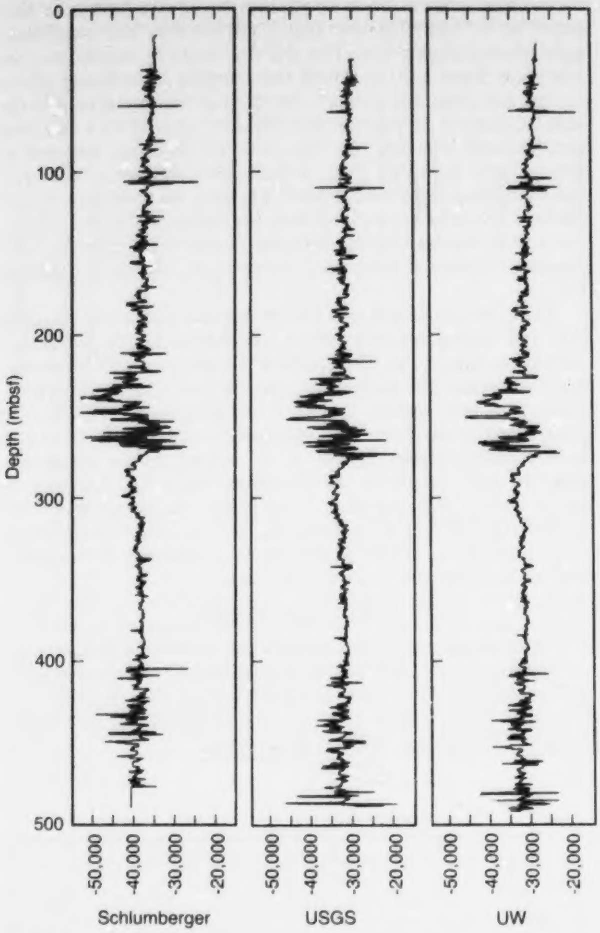

Figure 107. Vertical magnetic field measured in Hole 735B by the Schlumberger tool (left), the USGS tool (center), and the UW tool (right). Magnetic field is in nanoTeslas (nT). Center log has been corrected for drill-hole inclination, while the other two logs have not.

sembly immediately above the bit. It had been tested during Leg 102 and was successfully used during Legs 109 and 111 to measure permeability in the basalt layer of Holes 395A and 504B. This packer can be configured as either a single packer or a straddle packer; during Legs 109, 111, and 118, it was used as a single packer. With a single packer, permeability and pore pressure are determined as bulk values averaged over the interval between the packer seal and the bottom of the hole. Setting a single packer at several depths allows the permeability of the intervening zones to be determined.

With the TAM packer, the required hydraulic seal is achieved by pumping seawater down the drill pipe to fill an inflatable rubber and steel element, which expands and deforms against the borehole wall to isolate the formation below the seal (Fig. 108). The inflation mechanism is set in motion by first dropping a "go-devil," which performs two major functions:

1. To form a hydraulic seal within the packer and to direct the fluids pumped down the pipe first into the element for inflation, and then into the isolated formation for testing.
2. To carry the recorders that monitor the pressure data from which pore pressure and permeability are calculated.

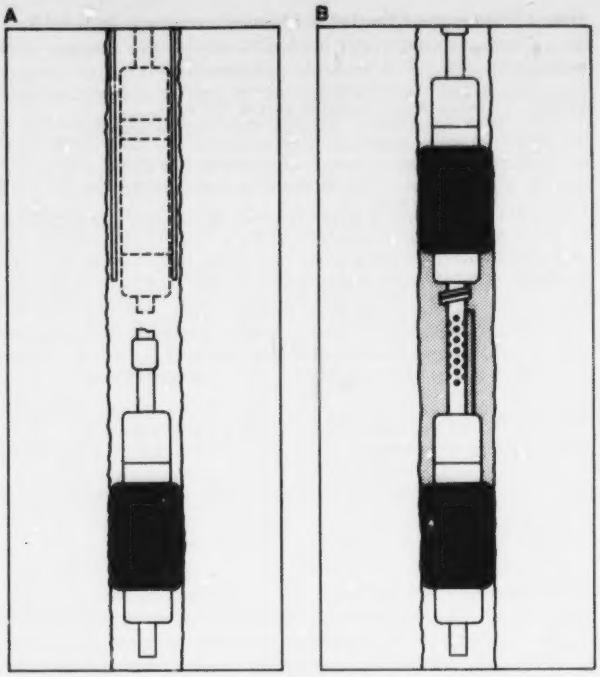

Figure 108. Sketches of inflatable drillstring packers. A. Single-element packer, which isolates the formation between the element and the bottom of the hole. B. Straddle packer, which separately isolates the zone between the elements and the zone between the lower element and the bottom of the hole.

The go-devil is allowed to fall freely down the pipe to the packer and is retrieved using the coring winch when the pressure recorders need to be reset.

During the Leg 118 permeability measurements, downhole pressure was monitored using two Kuster K-3 pressure recorders, S/N 9542 and 9685. These are self-contained, mechanical recorders that performed flawlessly, as they did during Legs 109 and 111. Their pressure sensors had been calibrated recently at the factory, and their time scales were carefully checked during Legs 109, 111, and 118. For each packer inflation point, both recorders were attached to the go-devil, for redundancy of data collection in the (unrealized) case of an instrument failure. These recorders can be set to run 3, 6, or 12 hr; for the Leg 118 experiments, they were set to run 6 hr, which was enough time to run two to four pulse and/or flow tests at each of two or three packer seats, before retrieving and redressing the go-devil while the packer was moved to another setting depth.

## Operational Summary

### *Leg 118 Permeability Measurements in Hole 735B*

The last day of scientific operations at Hole 735B was committed to a drill-pipe trip to run the drill-string packer into the hole. During this period, the go-devil was dropped and retrieved three times, and the packer was inflated six times to assess the variation of permeability in the formation (Table 17). During this sequence of measurements, fluid pressure, flow rate, and total volume pumped were measured at the surface, and fluid pressure was measured below the go-devil in the isolated intervals. During pulse tests, the small volume of fluid pumped was carefully recorded, to allow the compressiblity of the pressurized system to be checked, as suggested by Neuzil (1982).

**Table 17. Summary of Leg 118 packer measurements in Hole 735B.**

| Run | Activity |
|---|---|
| Go-Devil 1 | Packer Set 1 — packer at 49 mbsf (780 mbrf) |
| | 4 pulse tests — fast decay due to high permeability? |
| | unset packer with 20,000 lb pull. |
| | Packer Set 2 — reset packer at 47 mbsf (778 mbrf). |
| | 2 pulse tests — fast decay due to high permeability. |
| | 3 flow tests |
| | 100 strokes/min, with mud slug to verify packer seal. |
| | 50 strokes/min |
| | 30 strokes/min |
| Go-Devil 2 | Packer Set 3 — packer at 389 mbsf (1120 mbrf). |
| | 2 pulse tests — very slow decay due to very low permeability. |
| | Packer Set 4 — packer at 299 mbsf (1030 mbrf). |
| | 4 pulse tests — slow decay due to moderately low permeability. |
| | Packer Set 5 — packer at 223 mbsf (954 mbrf). |
| | 3 pulse tests — fast decay due to high permeability. |
| | 1 flow test — 50 strokes/min |
| Go-Devil 3 | Packer Set 6 — reset packer at 223 mbsf to verify previous results. |
| | 1 pulse tests — fast decay due to high permeability. |
| | 2 flow tests |
| | 30 strokes/min |
| | 50 strokes/min, with mud slug to verify packer seal. |

One pump stroke equals 5 gal.

Throughout the series of measurements, special care was taken to verify the hydraulic integrity of the testing system, which consisted of the rig pumps and lines, the drill string, the go-devil seals, and the inflated packer. Before dropping the first go-devil, the hydraulic integrity of the rig-floor circulation system was satisfactorily tested to 2000 psi, about twice the pressure used to inflate the packer or test the formation. At each packer-setting depth, the integrity of the drill-string and go-devil seals was satisfactorily tested by holding inflation pressure for about 10 min before locking the packers while inflated. The effectiveness of the packer seal against the borehole was demonstrated by the excellent quality of the slowly decaying slug test records in impermeable sections, and was tested in permeable zones by a method described next.

As mentioned above, the depths at which the packer was set were planned primarily based on logging results. The order in which the packer was inflated at these depths was left flexible, pending the results at the first setting depth, which was very shallow in the hole. We decided first to set the packer shallowly in the hole because there were a number of indications (e.g., superb core recovery, very high electrical-resistivity values and low-density values from the logs) that most of the formation might be quite impermeable. Setting the packer first as shallowly as possible allowed us to assess the permeability of the entire cored section; if the entire section had been impermeable, the remaining time on site would have been used for other purposes. However, the results at the first setting depth showed that there was significant permeability in the hole, and subsequent setting depths were run from deep in the hole back uphole to determine the variation of permeability with lithology and to locate the permeable zone(s).

The complete sequence of measurements is summarized in Table 17. All operations went smoothly, except for the very first packer setting, as follows: When the pulse test results at the first setting indicated surprisingly high permeability, we decided to verify that the packer element was properly sealing by resetting the packer at the same depth and repeating the measurements. However, we were unable to unset the packer smoothly as it required much more pull (20,000 lb) than normal to release the fluid inside the inflated element. For a short time, the packer was actually stuck in the hole, and we were not sure whether it was working properly. Nevertheless, when the packer was pressured up again 2 m shallower in the hole, it was reset smoothly and gave similar indications of high permeability somewhere in the isolated interval. Such indications could also have been produced by a "leaky" packer seal if the element had been damaged when pulling it free. The seal was tested by monitoring the television/sonar system, which was hanging immediately above the reentry cone, and a small slug of mud was pumped into the isolated interval, which was followed immediately by a standard constant-rate injection test that involved pumping seawater at 500 gal/min for more than 20 min. This amount of seawater was more than twice that required to pump the mud back out of the hole if the packer had not been sealing properly. No mud or other fluid was seen exiting the cone on the video, and the fluid pressure followed a reasonable curve for a successful injection test.

Thus, we concluded that the packer was operating correctly and was sealing properly; there was indeed highly permeable formation in the hole. The go-devil was retrieved and redressed, and the packer was moved deep in the hole and set at successively shallower depths to locate the permeable zone(s). The packer and go-devil operated smoothly until the drill string had to be pulled to depart the site. At the end of the last packer setting, the mud-slug/flow test described above was repeated; it again verified that the packer was sealing properly. When the packer was brought back on deck, the element was in nearly perfect condition, unlike several previous examples of shredded, melted, or otherwise frazzled elements.

## Preliminary Results

The pressure-time records from the downhole Kuster pressure recorders carried in the three go-devils are shown in Figures 109 through 111. It is clear from the variation in the responses to similar types of tests that there is a wide range of permeability in the formations cored in Hole 735B.

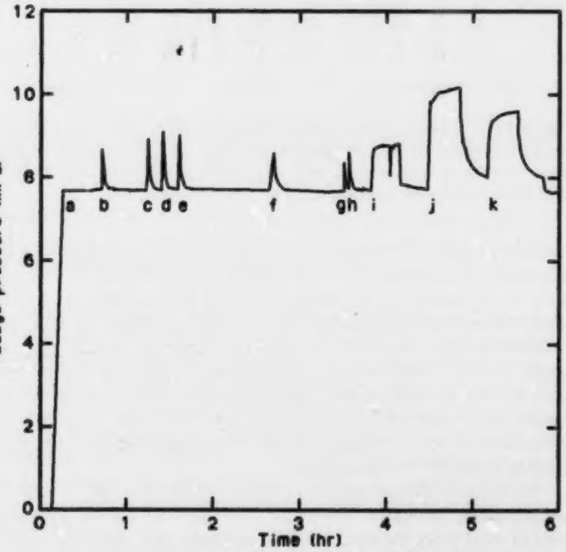

Figure 109. Pressure-time records from Kuster K-3 S/N 9582 for the two packer setting depths (49 and 47 mbsf) during the first run of the go-devil. a = Go-devil lands in packer and monitors hydrostatic pressure baseline. b = Pulse test resulting from packer inflation at 49 mbsf. c, d, e = Pulse tests. f = Deflate and pull packer free. g = Pulse test resulting from packer inflation at 47 mbsf. h = Pulse test. i, j, k = Constant-rate injections tests at 100, 50, and 30 strokes/min, respectively. The injection test at 100 strokes/min produced questionable data that are not a valid test of formation permeability, probably because of problems in switching from one rig-floor pump to the other.

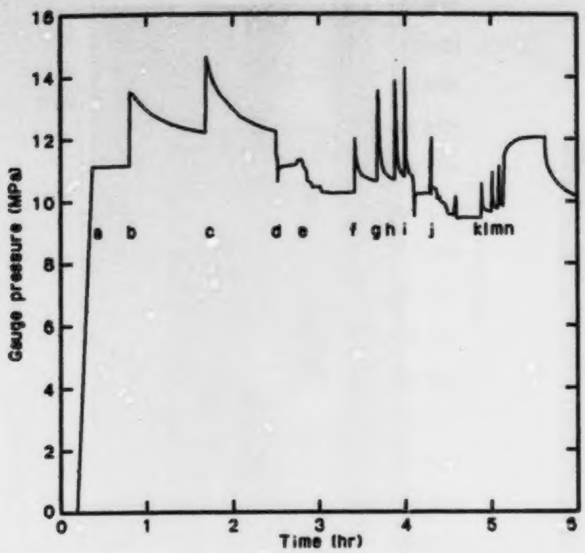

Figure 110. Pressure-time records for the three packer setting depths (389, 299, and 223 mbsf) during the second run of the go-devil. a = Go-devil lands in packer and monitors hydrostatic pressure baseline. b = Pulse test resulting from packer inflation at 389 mbsf. c = Pulse test. d = Packer deflation. e = Move packer to 299 mbsf. f = Pulse test resulting from packer inflation at 299 mbsf. g, h, i = Pulse tests and packer deflation. j = Move packer to 223 mbsf. k = Pulse test resulting from packer inflation at 223 mbsf. l, m = Pulse tests. n = Injection test at 50 strokes/min.

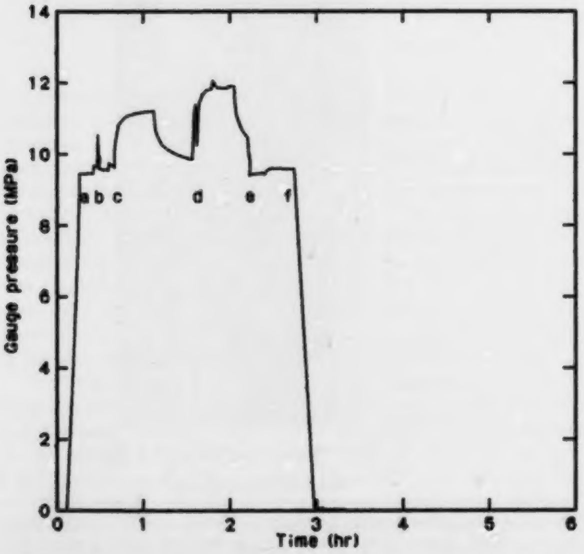

Figure 111. Pressure-time records for single-packer setting depth (223 mbsf) during the third run of the go-devil. The run ended after 3 hr for pulling pipe to depart the site on time. a = Go-devil lands in packer and monitors hydrostatic pressure baseline. b = Pulse test resulting from packer inflation at 223 mbsf. c = Injection test at 30 strokes/min. d = Mud slug and injection test at 50 strokes/min. e = Packer deflation. f = Retrieve go-devil and pull pipe to leave site.

When the packer was first set shallowly in the hole, pulse tests decayed very rapidly and the isolated zone accepted fluids pumped at high constant rates, indications of highly permeable formation(s) somewhere in the cored section. The second and third packer settings deep in the hole resulted in pulse tests of long decay times, indicative of low permeability in lithologic Units V and VI, particularly in the gabbros and troctolites of Unit VI. When the packer was set just above Unit IV at 223 mbsf, just 76 m above the impermeable gabbros of Units V and VI, pulse tests decayed rapidly and the isolated zone accepted fluids at similar rates and pressures as during the first packer set another 174 m shallower. Thus, it appears that the zone between 223 and 299 mbsf may contain most of the permeable formation in the entire cored section. However, the data must be processed carefully to assess whether all the transmissivity indicated below 49 mbsf is indeed concentrated between 223 and 299 mbsf.

The permeable zone between the packer sets at 223 and 299 mbsf includes the Unit IV iron- and titanium-rich, oxidized gabbros that are somewhat more porous than gabbros recovered from the rest of the hole, and the contact between Units IV and V. This sharp contact consists of a mylonite immediately above a brecciated zone (see "Lithostratigraphy" section, this chapter) that probably marks a major fault. The high injection rates achieved during the permeability measurements suggest that the breccia zone and fault may still be quite open.

As pressure data have not been completely processed, we are unable to determine accurately the values of permeability in Hole 735B. However, these values clearly span a large range, probably several orders of magnitude, as in Holes 395A and 504B. From the similarities in decay curves and constant flow results among the measurements in DSDP Holes 395A and 504B and ODP Hole 735B, we estimate that the permeabilities in the gabbros of Hole 735B span a similar range, as in the basalts of Hole 504B, on the order of $10^{-13}$m$^2$ in the upper section to $10^{-17}$m$^2$ in the deepest 100 m.

## BOREHOLE TELEVIEWER

### Introduction

The borehole televiewer (BHTV) is an acoustic device that scans the wall of the borehole, producing an image of the reflectivity of the rock surrounding the hole as a function of depth and azimuth. A piezoelectric transducer, which is mounted on a central shaft rotating three times per second, transmits and receives a high-frequency acoustic pulse 600 times per revolution. Two transducers are mounted on this shaft, which allows either a 1.3-MHz or a 400-kHz pulse to be used as a source. The higher-frequency source reveals more details of the wall surface, while the lower-frequency source has better penetration and can produce an improved image in a rough-walled borehole. The pulse is transmitted through the borehole fluid, reflected from the wall of the borehole, and received again at the transducer. The amplitude of the returning signal is recorded and displayed as brightness on a three-axis oscilloscope. The oscilloscope image is thus an acoustic picture of the reflectivity of the borehole wall, where the azimuth varies along the *X*-axis and depth varies along the *Y*-axis. The left-hand edge of the image is aligned with the local magnetic north in the borehole using a downhole fluxgate magnetometer.

The raw data are recorded on a specially formatted video cassette for final playback and processing. The amplitudes and traveltimes of the received pulses are also recorded on magnetic tape by digitizing the televiewer signal during playback. This traveltime log may be used to yield a three-dimensional cylindrical projection of the borehole as a function of depth and azimuth in the well, producing a 360° caliper log.

The scientific objectives addressed by BHTV logs include (1) the location and orientation of fractures intersecting the hole; (2) the determination of structural features, such as bedding or brecciation; (3) the measurement of borehole diameter, ellipticity, and surface roughness; and (4) the determination of the orientation of the principal horizontal stresses from the azimuth of borehole breakouts observed in the time-domain images. However, some limitations of the BHTV log should be recognized. First, as the log is effectively a point measurement with depth, ship heave may cause irregular tool motion and confuse the analysis and interpretation of the log. Second, severe borehole deviation or ellipticity or decentralization of the tool will degrade the image because the beam will no longer be perpendicular to the borehole wall at all azimuths. This effect can be recognized in the time-domain image. Third, the BHTV cannot recognize features that do not affect either the roughness, reflectivity, or radius of the borehole. BHTV images recorded in Hole 735B are briefly discussed next.

### Operations

The BHTV log from Hole 735B was recorded on 8 December 1987 while logging upward at a rate of 1.5 m/min from 489.0 to 13.0 mbsf. The borehole caliper log shows hole diameter varying from 10 to 12 in., and borehole deviation logs show that the hole was inclined between 4° and 6° from vertical. The first BHTV pass on 7 December was aborted because of severe centralization problems with the tool in the noncylindrical hole, although at the time, an electronic malfunction was suspected. The effects of poor centralization and ellipticity remained as dark vertical bands apparent in the BHTV amplitude images even after improved centralization using three 3-armed bowspring sections: the standard upper BHTV centralizer, the lower multichannel sonic centralizer, and a through-wired temperature tool centralizer borrowed from J. Scott (USGS). Determining the effect of borehole shape requires additional digital processing of traveltime data.

The BHTV log in Hole 735B was recorded with the wireline heave compensator, although its operation was not optimal in the low sea state present during logging. In addition, between 207 and 277 mbsf, the wireline heave compensator was not operating because of a malfunction of the heat exchanger. Ship heave introduced some periodic changes in scanning coverage, but these effects were easily observed and corrected in the digital images.

### Data

The BHTV log was digitally processed from 489.0 to 240.0 mbsf using shore-based MassComp computer equipment. The upper 240 m must still be processed. The gabbro interval studied has smooth and cylindrical borehole walls and isolated fracturing. Planar features, such as fractures, appear as dark bands (low amplitude and longer traveltime) in horizontal or sinusoidal curves in the unwrapped BHTV image. Two examples of steeply dipping, planar features are shown as traveltime images in Figures 112 and 113 at 288 and 417 mbsf. Fractures are also more clearly observed in traveltime images than in amplitude images. The effects of eccentricity of the tool are obvious as wide vertical banding and can be easily distinguished from the effects of fractures. These two isolated fractures both strike north-northwest and dip 73° to 77° west-southwest.

In Figures 114 and 115, cylindrical net projections of two fractures at 292.5 and 302.5 mbsf are presented at three viewing angles. These isolated features dip about 70° west-southwest, consistent with the other fractures depicted in Figures 112 and 113. Horizontal offsets in the fracture plane and variable spacing of the traveltime net result from uncompensated ship heave. This effect may be corrected later by editing the data.

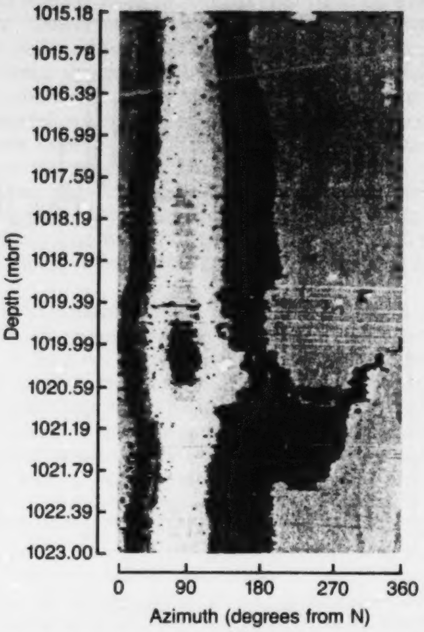

Figure 112. Digitally processed borehole televiewer traveltime image. Tool decentralization appears as diffuse vertical banding. An isolated fracture at 1020 mbrf (288 mbsf) is evident as a dark sinusoidal band that dips about 73° west-southwest (see text).

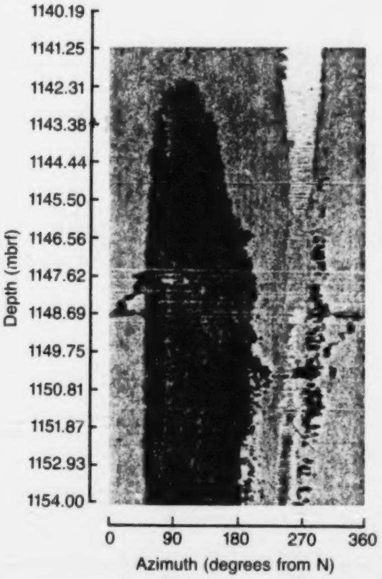

Figure 113. Digitally processed borehole televiewer traveltime image showing some tool decentralization and a large fracture dipping about 77° west-southwest.

The location of these major fractures at 288, 292.5, and 302.5 mbsf corresponds to the location of decreases in compressional velocity and shear semblance (see "Sonic Logs" section, this chapter). These also occur where fluid permeability, as determined from packer tests, may decrease with depth, although

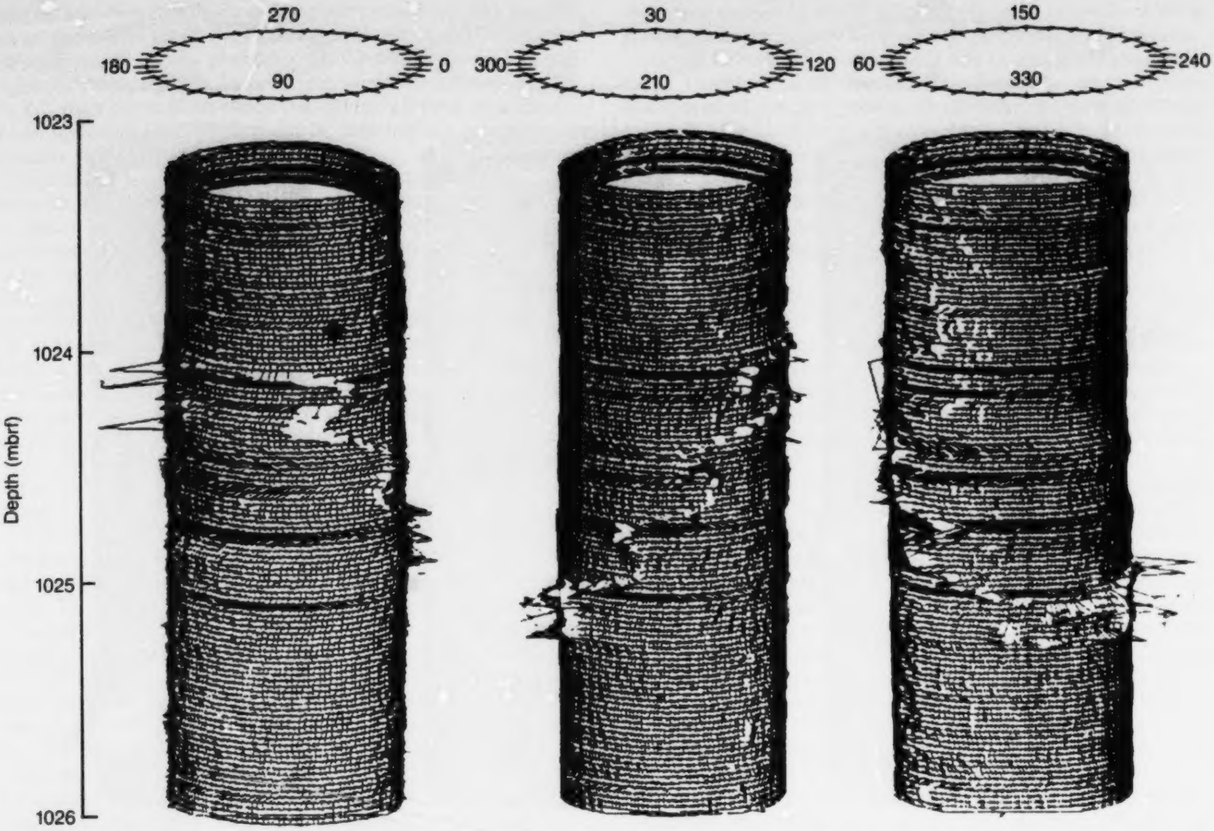

Figure 114. Cylindrical net projections at three viewing angles (90°, 210°, 330°) showing the intersection of a dipping fracture with the borehole at 1024.5 mbrf (292.5 mbsf). Horizontal offsets in the fracture plane and variable spacing of the traveltime net result from uncompensated ship heave.

the precise depth of this change cannot be determined (see "Permeability Experiments" section, this chapter). The fracture observed at 417 mbsf is not associated with major decreases in sonic velocity or semblance, nor with high permeability. The interval just below the iron-titanium oxide-rich gabbro is also rich in hydrothermal alteration minerals (see "Metamorphism and Alteration" section, this chapter) and corresponds to a positive temperature anomaly (see "Temperature Measurements" section, this chapter). It appears, then, that at least some of the fractures near 290 mbsf are open and active in fluid transport. The fracture at 417 mbsf, or others in the lower interval of this hole, is filled or closed and apparently does not transmit fluids.

In the lower 250 m of the hole, only these major fractures were observed from preliminary data processing. Smaller and subhorizontal features may appear after additional processing of the BHTV data. Note, however, that the resolution of low-angle features in BHTV images is about 20°, i.e., features dipping between 0° and 20° do not appear significantly different from horizontal ones. In any event, further examination and processing of the BHTV images in the upper interval of the hole will be necessary to produce a complete log. These results may show the severe fracturing and foliated intervals usually observed from the recovered core or indicated from high sonic attenuation and porosity observed from logging results.

## SUMMARY AND CONCLUSIONS

A major long-term goal of ODP has been to sample *in-situ* sections of the lower oceanic crust and upper mantle. Prior to Leg 118, only small amounts of gabbro and peridotite had been cored from anomalous occurrences, chiefly along the Mid-Atlantic Ridge and some continental margins.

At Site 735, we continuously cored a 500.7-m-thick section of gabbro on the wall of the Atlantis II Fracture Zone. Core recovery averaged 87% for the entire hole and exceeded 95% in the lower 350 m. The recovered core provides a unique opportunity to study (1) the petrology and structure of the lower oceanic crust, (2) the nature of magma chamber evolution at a slow-spreading ridge, and (3) the physical properties of layer 3 as determined from downhole and sonic measurements.

Site 735 is located on a shallow platform in about 700 m of water on the east rim of the transform. This platform, about 9 km long in north-south direction and 4 km wide, is one of a series of uplifted blocks that are connected by saddles to form a long, linear ridge parallel to the Atlantis II transform. The entire ridge is elevated from 2 to nearly 6 km relative to the floor of the adjacent transform and from 1 to 4 km relative to the ridge-generated crust lying to the east. The topographic relief along this "transverse ridge" varies considerably, particularly between uplifted blocks, which may be as much as 2 or 3 km higher than the intervening saddles. The uplifted blocks are highly irregular in shape, defined by steep slopes commonly associated with major normal faulting in such terrains, and may represent simple horsts uplifted relative to both the rift valley floor at which the crust originated and the adjacent ocean crust to the east. Such topographic features are found in many fracture zones and are commonly underlain by upper mantle and

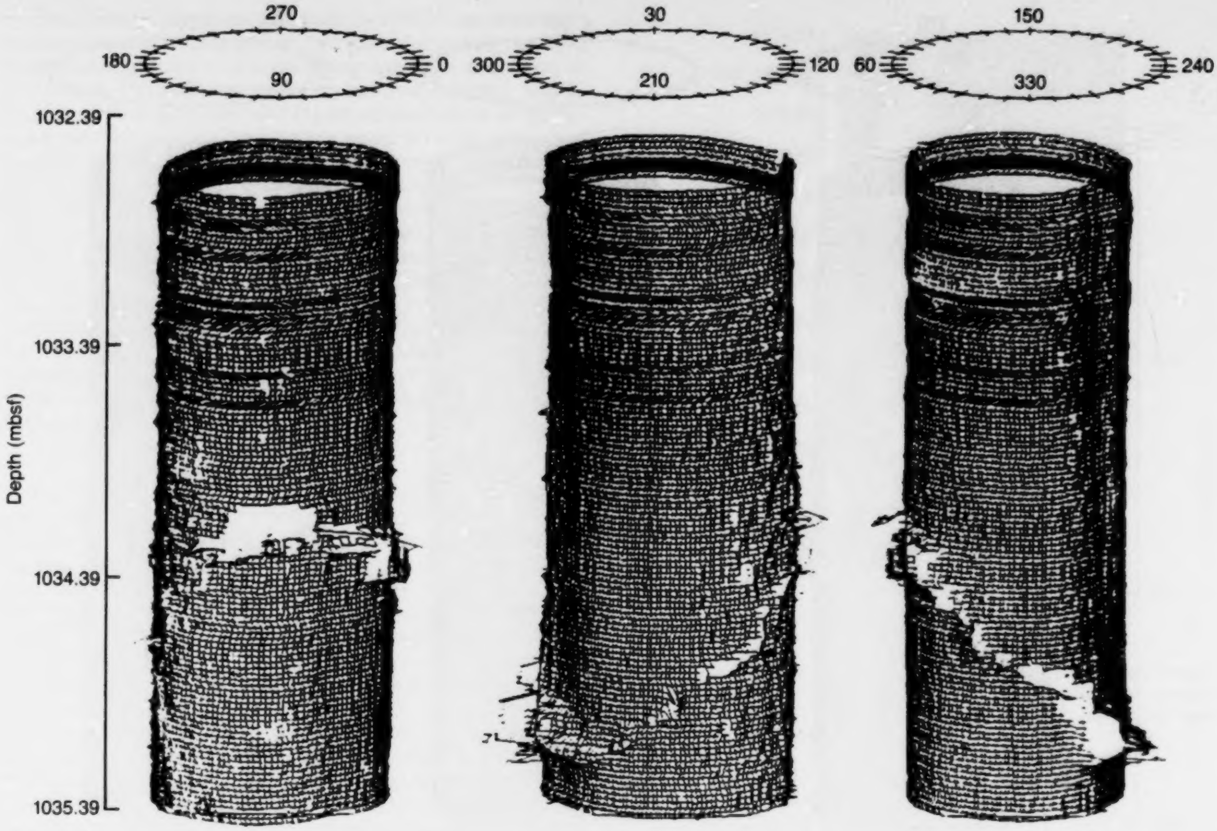

Figure 115. Cylindrical net projections showing the intersection of a dipping fracture at 1034.5 mbrf (302.5 mbsf).

lower crustal rocks (Bonatti, 1978; Engel and Fisher, 1975; van Andel et al., 1971).

The platform at Site 735 has a remarkably flat surface, which suggests that it is a wave-cut feature. Its position in the magnetic anomaly pattern on the east transform wall suggests a crustal age of about 12 Ma. A television/sonar survey conducted before drilling revealed basement outcrops locally mantled with thin layers of sediment. Many of the outcrops have a well-developed, steeply dipping foliation and are cut by a regular pattern of faults or joints.

An unsupported test spud-in, using the turbine coring motor, recovered 0.1 m of gabbro from Hole 735A. Consequently, the hard-rock guidebase was deployed and drilling commenced in Hole 735B. Although this was only the second time that a guidebase had been used, deployment proceeded smoothly and required only two days. Once the guidebase was cemented in place on the seafloor, the coring motor was used to start a hole and to drill to a depth of 60 m. When the hole was deep enough to provide lateral support for the standard rotary coring system, we used it to drill to 500 mbsf. A newly developed navidrill was then tested in the hole and cut another 70 cm. The entire 500.7-m-deep hole was drilled in 17 days, resulting in an average rate of penetration of 30 m/day.

A total of 435 m of igneous and metamorphic rock was recovered from Hole 735B for an average recovery of 87%. However, below about 150 m the recovery averaged 95%, providing a nearly complete section of part of crustal layer 3. The recovered material includes olivine gabbro, olivine-bearing gabbro, two-pyroxene gabbro, iron-titanium oxide gabbro, troctolite, and microgabbro with rare basalt and trondjhemite. These rocks have undergone varying degrees of plastic and brittle deformation and many have well-developed foliations.

Six major lithologic units were recognized in the sequence, based primarily on igneous mineralogy, mineral compositions, and degree and style of deformation.

Lithologic Unit I is a 39.5-m-thick sequence of foliated metagabbro with porphyroclastic to mylonitic textures. Rock types include poorly foliated metagabbro, porphyroclastic metagabbro, mylonite, gneissic metagabbro, and augen gneissic metagabbro. Igneous textures have been completely destroyed, and the rocks now consist chiefly of neoblasts of plagioclase, clinopyroxene, and amphibole. Relic porphyroclasts of plagioclase, orthopyroxene, clinopyroxene, iron-titanium oxides, and rare olivine suggest that the protolith was a two-pyroxene gabbronorite or olivine gabbronorite. A few iron-titanium oxide-rich layers in this unit are probably secondary because the oxides fill fractures and pore spaces in the gabbros.

Lithologic Unit II consists of 140.5 m of olivine and olivine-bearing gabbro. The upper contact is drawn at the first appearance of clearly igneous textures, and the lower boundary is a rapid transition to gabbro with more orthopyroxene and more sodic plagioclase. Most of the rocks are mesocumulates that commonly have primary layering defined by size variations. Alternating bands of olivine-rich and olivine-poor gabbro reflect rare modal layering. These gabbros consist of plagioclase (40%–70%), clinopyroxene (30%–50%), olivine (0%–25%), and orthopyroxene (0%–3%), along with traces of iron-titanium oxides, primary brown amphibole, and sulfides. Chemically, they are fairly primitive rocks with MgO contents between 9 and 12 wt% and magnesium numbers between 0.78 and 0.85. Interlayered iron-titanium oxide-bearing gabbros commonly have igneous textures in which the oxide minerals are closely intergrown with pyroxenes. A few pyroxene-rich layers containing inverted pigeonite were probably formed from significantly more evolved liquids than those from which the olivine gabbros crystallized. Some mylonitic and porphyroclastic intervals are present, particularly in the upper part of the unit.

Lithologic Unit III is a 44-m-thick sequence of olivine gabbro with intervals of iron-titanium oxide gabbro. These gabbros are macroscopically similar to those of Unit II but have significantly more enriched compositions. The upper contact is gradational and is defined by the appearance of sodic plagioclase ($An_{40-45}$), low-calcium pyroxene, and iron-rich olivine. This contact coincides with a change in chemical composition from olivine gabbro with 12-13 wt% MgO to gabbro with 8-9 wt% MgO. A reappearance of more magnesian olivine gabbro at 211 mbsf coincides with a geochemical break between the upper and lower parts of Unit III. A well-developed igneous lamination is steeply dipping in the upper part of the unit but flattens with depth. Mylonitic and foliated zones are common, and the lower contact of Unit III is marked by a 60-cm-thick zone of mylonite.

Lithologic Unit IV is composed of 48 m of iron-titanium oxide-rich gabbro. The Unit III/Unit IV contact is gradational, and the lower boundary is marked by a 3-m-thick layer of mylonite. These gabbros have more abundant opaque minerals (10% or more) and less olivine than those of Unit III. They consist chiefly of plagioclase, clinopyroxene, and iron-titanium oxide, with minor amounts of olivine, calcium-poor pyroxene, reddish-brown hornblende, apatite, and sulfide. Like those of Unit III, these rocks have relatively sodic plagioclase and iron-rich olivine. The iron-titanium oxide gabbros have granular textures, commonly with cumulus plagioclase and clinopyroxene. Olivine is typically intergranular and the iron-titanium oxides, mostly ilmenite and magnetite, form intergranular to poikilitic masses enclosing plagioclase and clinopyroxene. These rocks have iron oxide contents up to 30 wt% and $TiO_2$ contents up to 9 wt%. The magnesium numbers of these rocks are the lowest of all samples analyzed from Hole 735B and range from 0.32 to 0.51. On land, these rocks might be investigated as a possible ore deposit. A felsic intrusion breccia having trondjhemite veins occurs at two levels in the unit.

Lithologic Unit V consists of 131.5 m of relatively uniform olivine gabbro characterized by a scarcity of iron-titanium oxides and low-calcium pyroxene. Most of the gabbros are mesocumulates, and some exhibit primary grain size layering. They are mineralogically and chemically similar to those of Unit II. Small changes in mineral proportions are shown by the presence of a thin troctolite layer and several plagioclase-rich zones. Zones of brecciation are common and contain felsic veins of epidote and albite.

Lithologic Unit VI is an interval of olivine-rich gabbro having frequent layers and intrusions of troctolite. The gabbros are similar to those of Unit V but have consistently higher modal percentages of olivine. Grain size layering is common, and some lenses and layers of microgabbro occur. The troctolite and troctolitic gabbros are interlayered with the olivine gabbros. Most are fine-grained rocks with granular textures and are interpreted as small intrusive layers. They consist on average of 43% olivine, 53% plagioclase, 3% clinopyroxene, and 1% spinel, with trace amounts of sulfides. These are the most mafic rocks encountered in Hole 735B, with up to 25 wt% MgO and magnesium numbers that range from 0.83 to 0.87. The fine-grained, granular textures indicate a noncumulate origin. These compositions are probably close to the original liquids. A few coarse-grained iron-titanium oxide gabbros are also present; there is an intrusion of orthopyroxene plus oxide plus apatite gabbro near the upper contact. Unit VI also has frequent intervals of metagabbro characterized by mylonitic to porphyroclastic textures.

Contacts between Units I and II and IV and V are clearly tectonic. Undeformed or poorly foliated gabbros are commonly juxtaposed with augen gneissic or mylonitic gabbros and metagabbros, which indicates very high strain gradients. The foliated gabbros obviously experienced less total strain than the augen gneissic gabbros, which in turn are less strained than the mylonites. However, the strain was far from linear, and that accommodated by a 10-cm-thick mylonitic band probably was greater than that accommodated by a 100-m-thick section of poorly foliated gabbro.

Veins and fractures generally dip 40° to 90°, with a strong peak at 60° to 65°. Vein dips are skewed toward steep inclinations, and the skewness increases below 90 mbsf, suggesting that the stress field deeper in the hole was rotated with respect to that higher in the hole. The mean dip of both veins and foliation decreases downward in the hole, which suggests that deformation took place along listric normal faults that flatten downward.

The rocks from Hole 735B were subjected to varying degrees of metamorphism and alteration. An early stage of dynamothermal metamorphism produced highly foliated porphyroclastic, gneissic, and mylonitic textures. Highly deformed rocks are most abundant in lithologic Unit I but also occur intermittently elsewhere in the section. This high-temperature event was followed by brecciation and static alteration associated with brittle deformation. The static alteration was controlled by permeability and is manifested by numerous veins (0.5-2 cm wide) filled largely with hornblende and sodic plagioclase. Clinozoisite, epidote, and minor prehnite occur in the lower parts of the core. A few silicic veins containing diopside, hornblende, sphene, clinozoisite, and albite are also present. In undeformed gabbros, static alteration resulted in development of coronas of hornblende, tremolite, talc, clinozoisite, magnetite, chlorite, sphene, epidote, and phlogopite(?) around the primary igneous minerals. A late stage of oxidative alteration is reflected in carbonate plus hematite plus smectite pseudomorphs of olivine and orthopyroxene. These occur sporadically in the upper 256 m of the core and are particularly abundant from 33 to 39 mbsf. Oxidative alteration is also observed in brecciated zones at 180, 275, and 330 mbsf.

Paleomagnetic intensities are variable, generally in the range of other oceanic gabbros but up to $> 2.5$ emu/cm$^3$ in some of the iron-titanium oxide gabbros. Magnetic susceptibilities average about $100 \times 10^{-6}$ cgs and are significantly lower than values from gabbros of the Kane Fracture Zone (Fox and Opdyke, 1973). Again, the highest values are in the iron-titanium oxide gabbros. Natural remanent inclinations are all steep and about equally divided between normal and reverse. Stable inclinations are reversed and average 65° ± 15°. The theoretical inclination for the site is $-52°$, so the observed inclinations are somewhat steeper than expected. Logging in the hole shows that it has an average tilt from vertical of about 5° in a north and east direction, so that the inclinations are even more anomalous with respect to the present mean field.

Results of logging and downhole measurements reveal interesting structural and physical properties of the rock penetrated by the hole. Compressional-wave seismic velocities in the gabbros range from 6.5 to 7.0 km/s, both on rock samples and *in situ*, confirming expectations from the low porosities measured (less than a few percent) for relatively high velocities in the bulk rock and that fracture porosity is not significant throughout the section. Physical-properties measurements show seismic anisotropy up to 10%, particularly in some of the foliated rock. A borehole multichannel seismic experiment indicated that *in-situ* seismic velocity increases somewhat (5%-10%) with depth over the hole. Grain (matrix) densities obtained average about 2.9 g/cm$^3$ over the hole from logs, and the caliper log showed a relatively uniform diameter (±1 in. or less), generally changing only gradually with depth.

One of the more interesting logs at this site was the laterolog, which showed variations of electrical resistivity of four orders of magnitude downhole (~4 to 40,000 ohm-m). The highest values are to be expected from silicate rock of low porosity, but lower values are not generally correlated with higher porosity. The most prominent low-resistivity zone occurs throughout Unit IV and probably results from the high mineral conductivity of the iron-titanium oxides. Smaller-scale variations (a few meters) in the units below may reflect the same conductivity mechanisms.

The borehole televiewer showed that most of the hole wall is relatively smooth, with occasional linear and sinusoidal features, which probably indicate small fractures that cut the borehole. Broader, near-vertical bands of light and dark reflectivity may indicate noncircularity of the borehole cross section, although further processing and analysis may be needed to distinguish the similar effects of a decentralized tool.

Four magnetometer sondes were run in the hole: (1) the Schlumberger three-component tool used primarily for hole inclination and orientation, (2) a USGS three-component magnetometer, (3) a USGS susceptibility tool and a UW/LDGO combined 3-component magnetometer, and (4) a susceptibility tool. The magnetometers showed large and similar variations in the fields measured in the hole, especially in the iron-titanium oxide-rich zone where the fields are up to 50% greater and more variable. Although susceptibility also varies more in this zone, most of the variability is probably due to the remanent component, much of it unstable, as deduced from samples examined in the Paleomagnetics Laboratory aboard ship.

A borehole packer experiment indicated low fluid permeability below about 272 mbsf, with higher values (by several orders of magnitude) above this level. Because of the low porosity, the higher permeability is unlikely to be related to bulk properties of the rock, but probably reflects fracture permeability, at least at a few zones. The temperature log shows a very low or even negative gradient in the hole, further evidence of the effects of seawater advection even with low porosity.

More comprehensive studies of the rock samples recovered and the data obtained will better define the origin, tectonics, and physical state of this unique section of material believed to represent the lower oceanic crust.

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**Ms 118A-107**

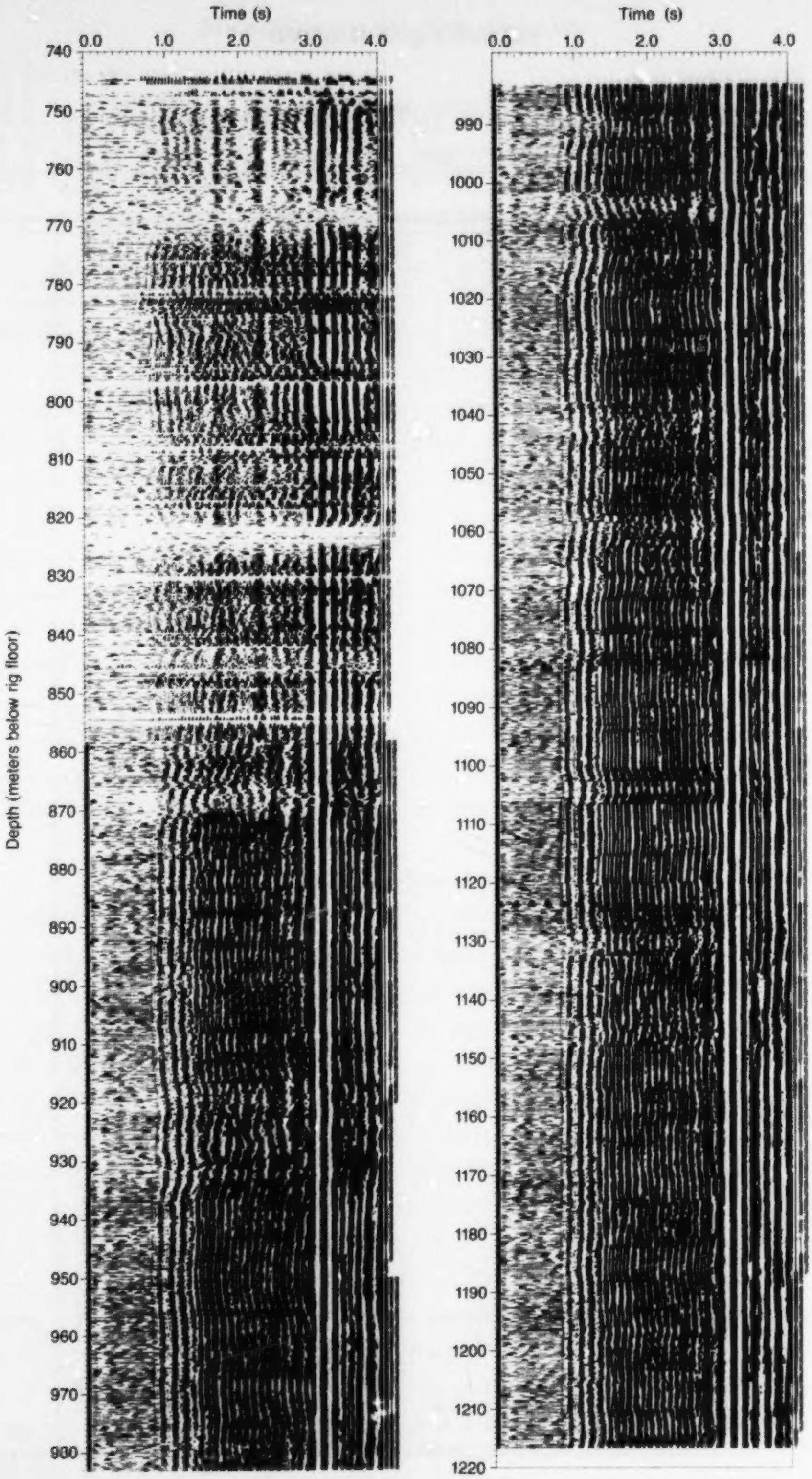
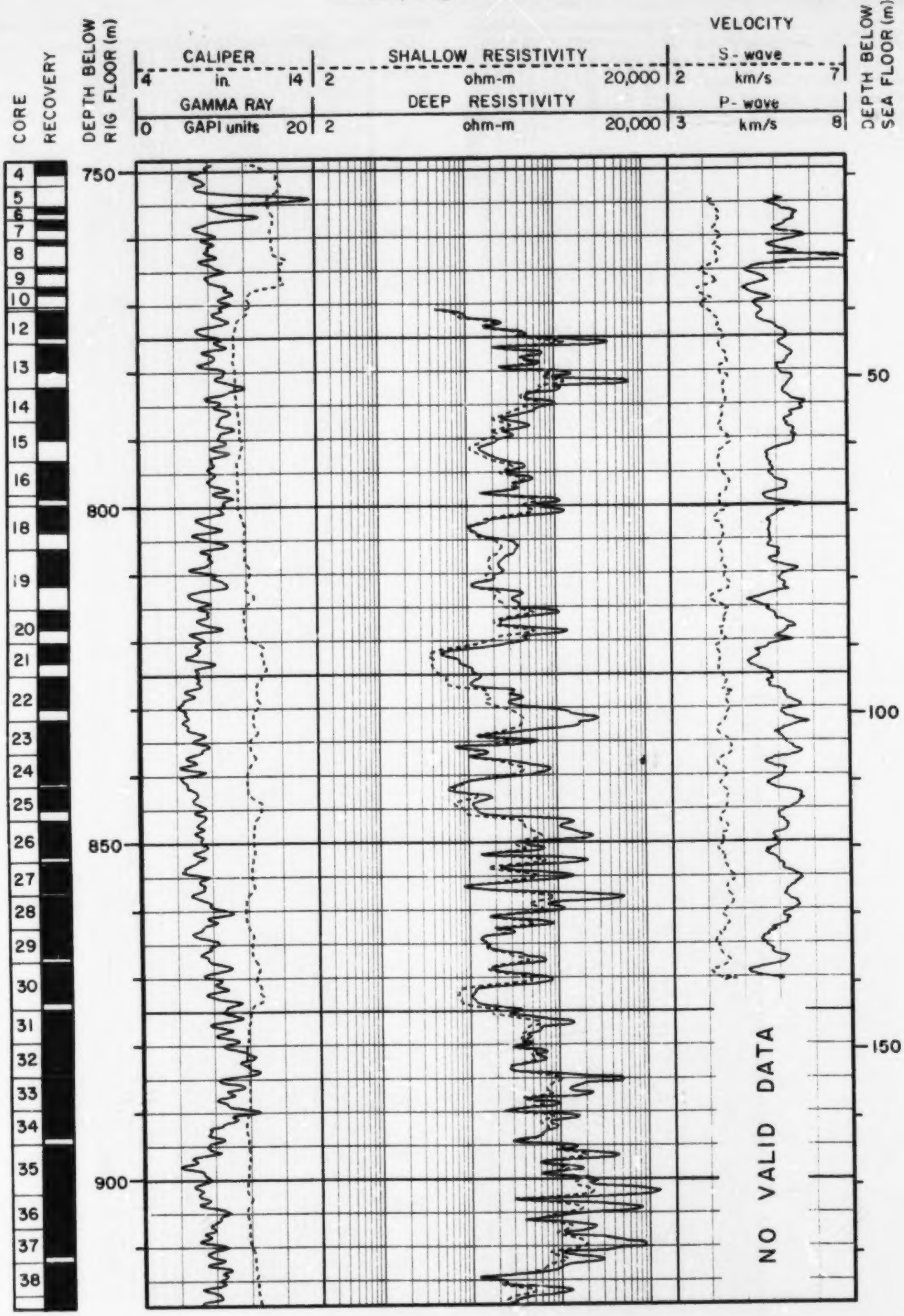
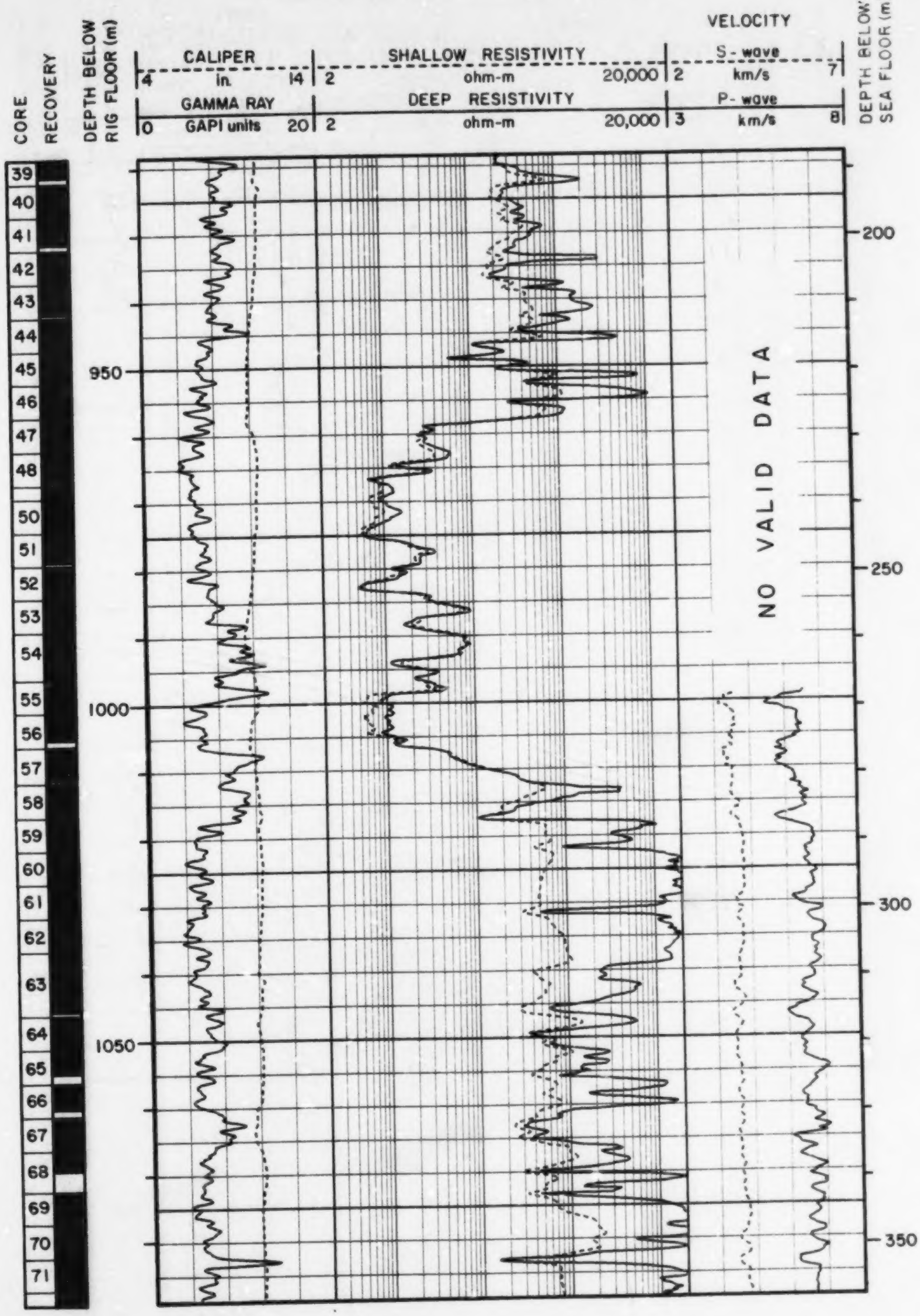


Plate 1. Variable density plot of receiver 6 (4.57 m offset) waveforms from 745.0 to 1216.6 mbrf (13.0–484.6 mbsf). Waveforms from receiver 12 are shown for the upper 100-m interval to provide consistent source-receiver offset for the plot. This interval also is plotted at a scale of 5X.

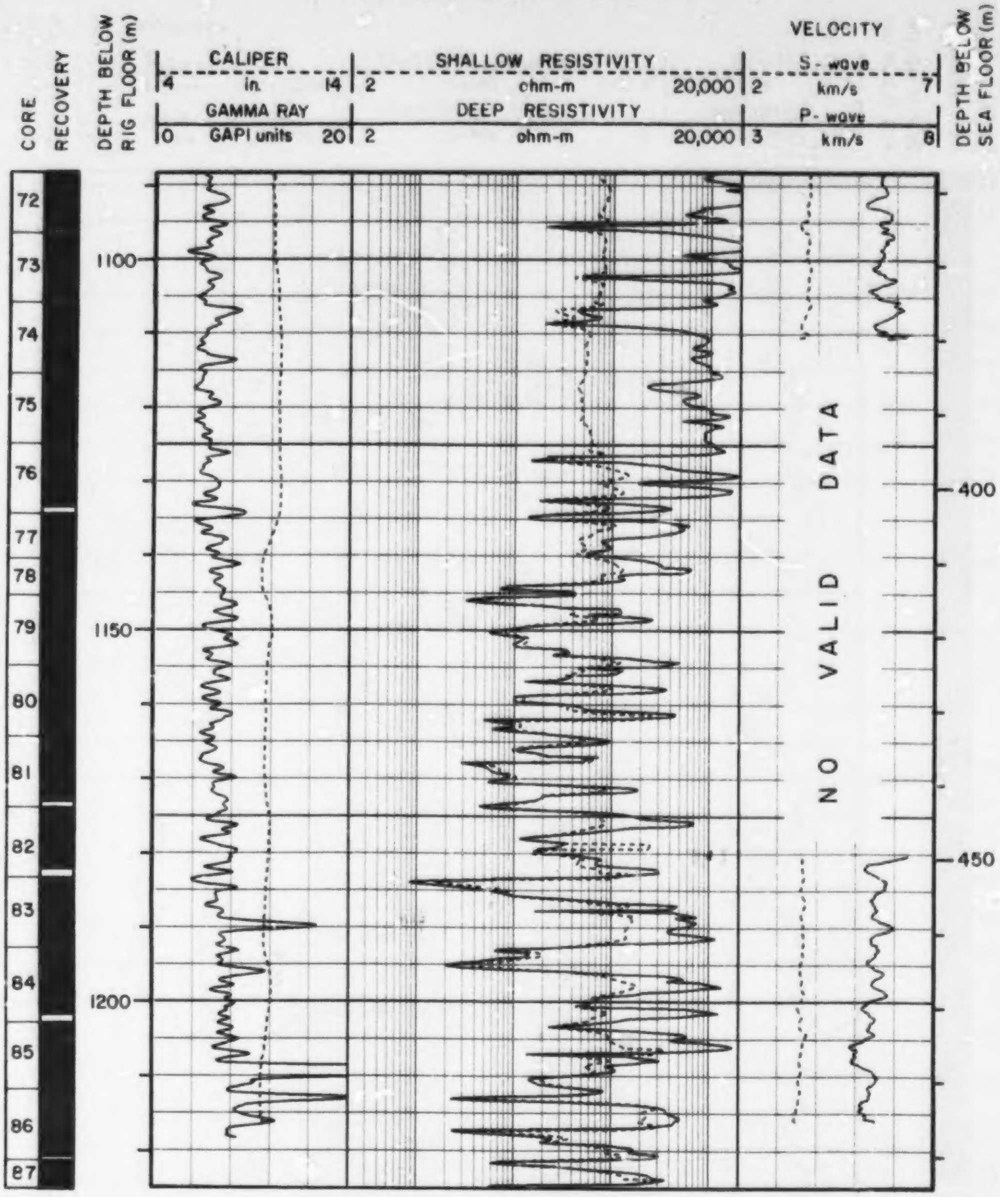
## Summary Log for Hole 735B



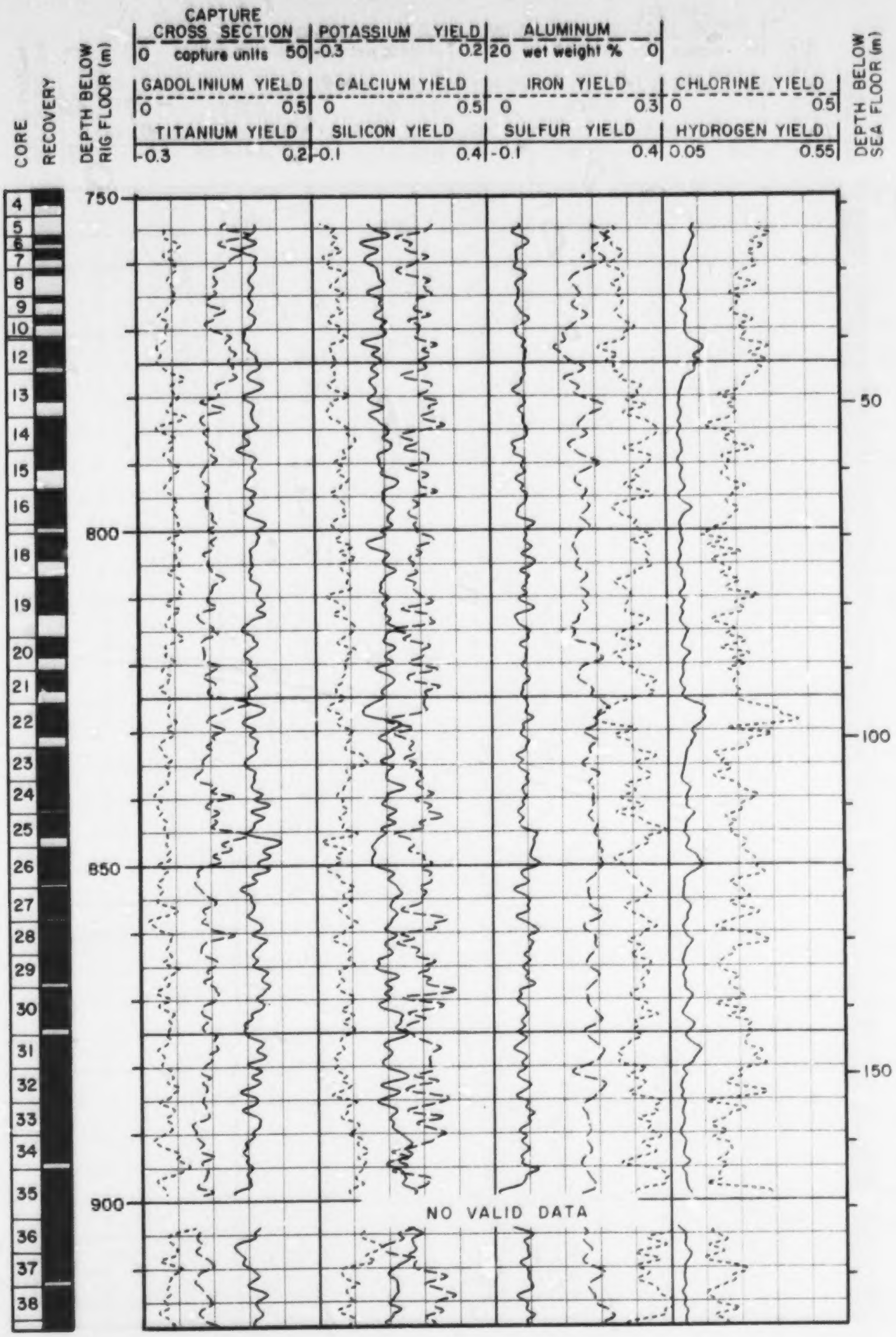
## Summary Log for Hole 735B (continued)



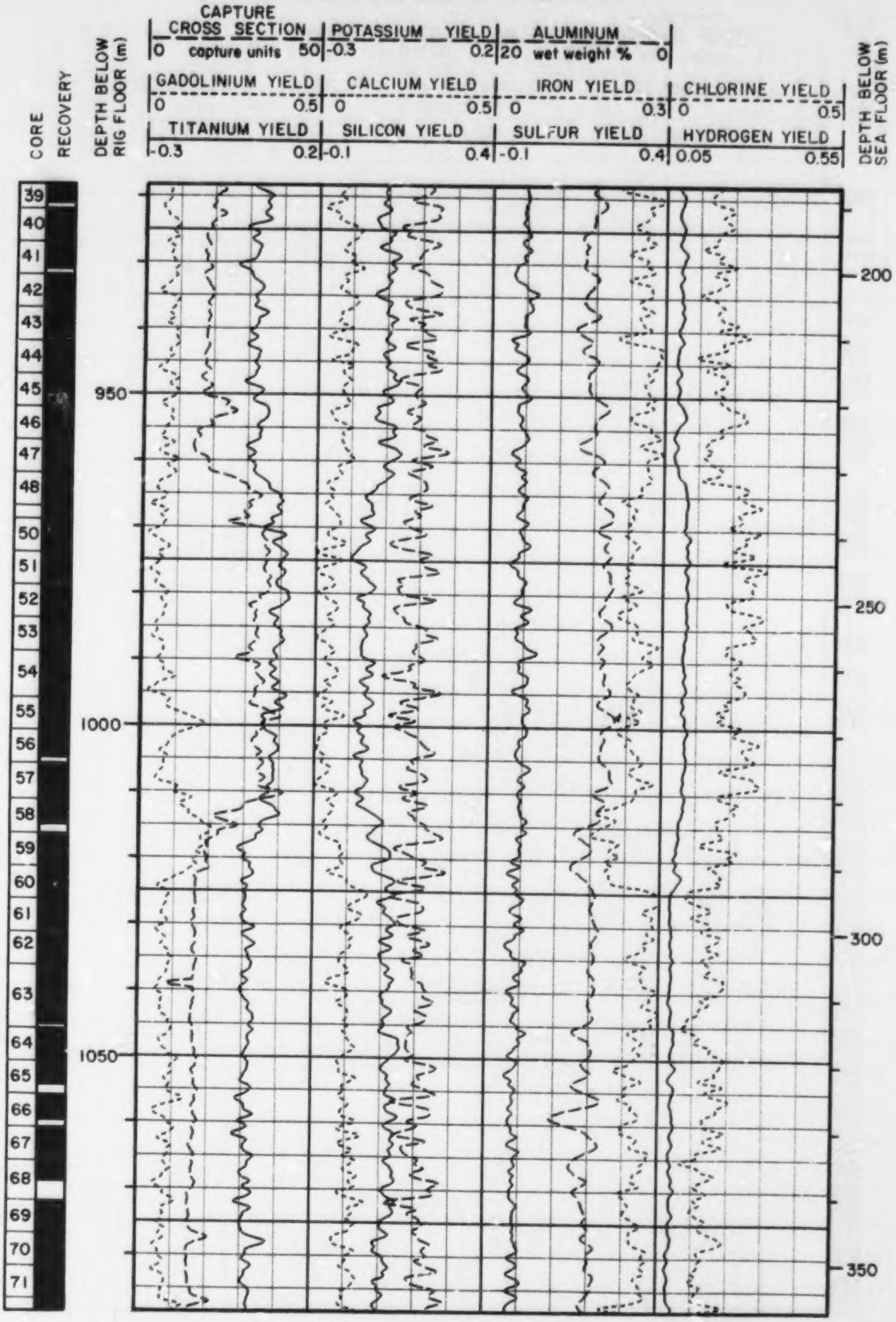
**Summary Log for Hole 735B (continued)**



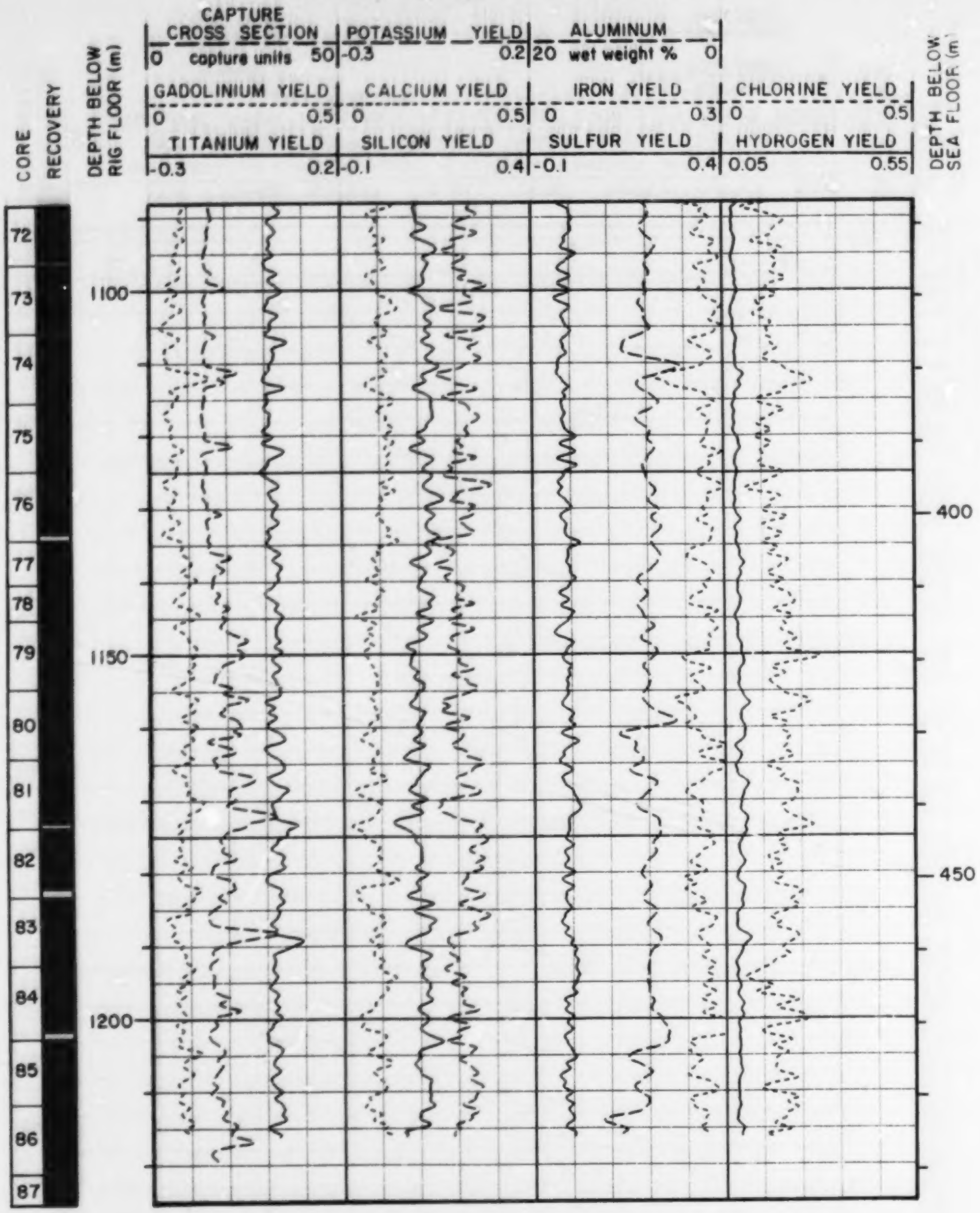
**Summary Log for Hole 735B (continued)**



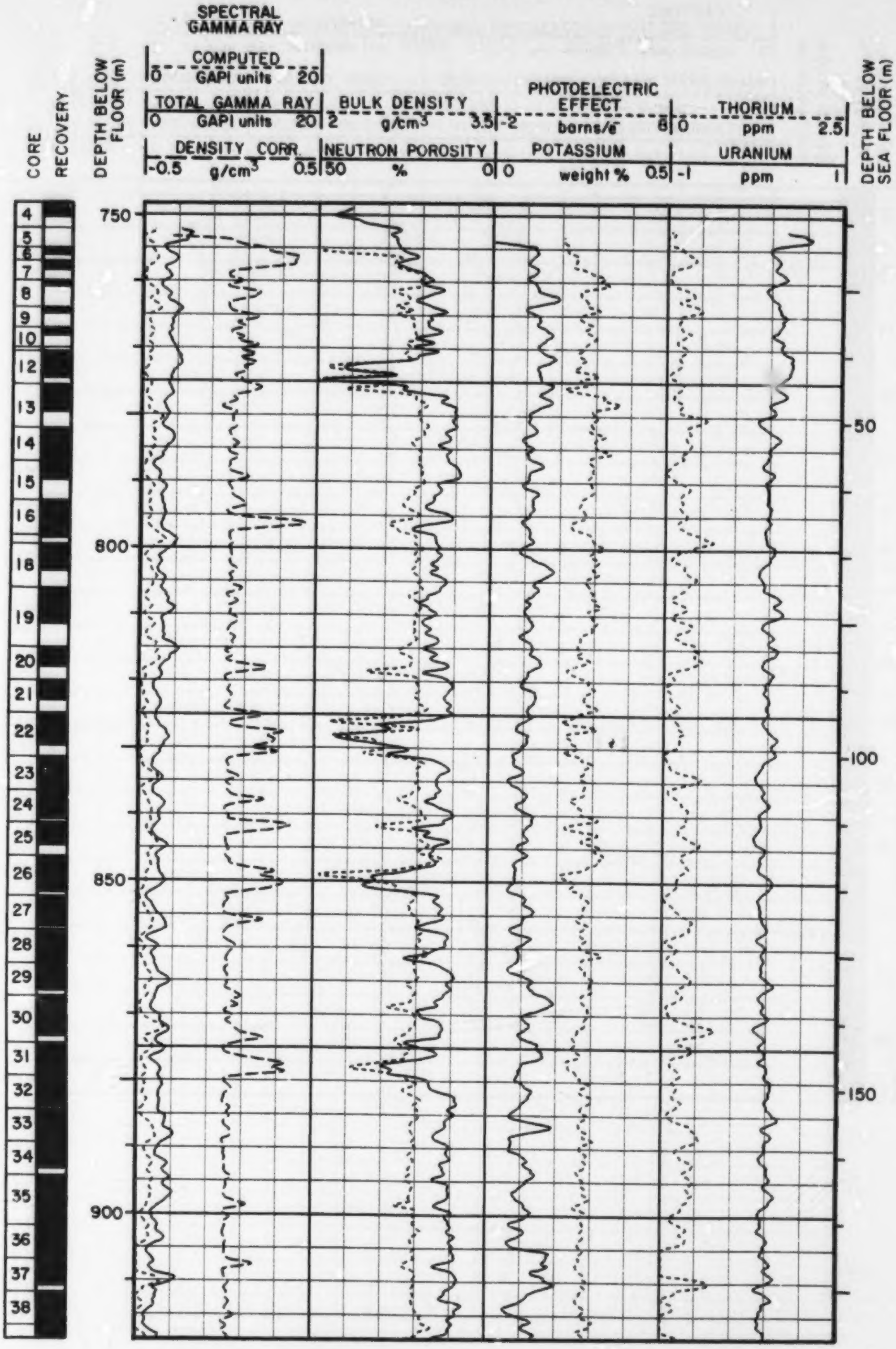
## Summary Log for Hole 735B (continued)



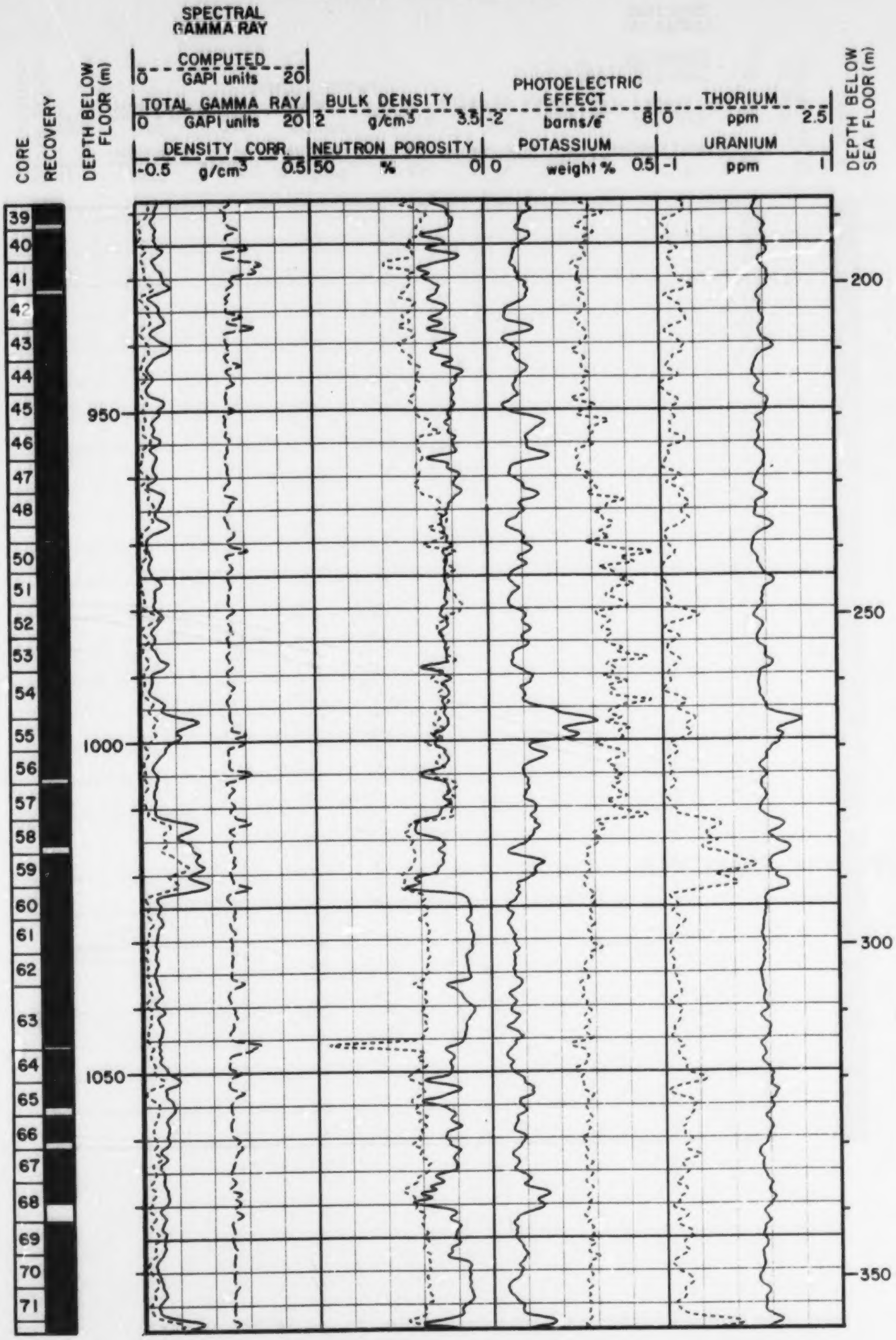
## Summary Log for Hole 735B (continued)



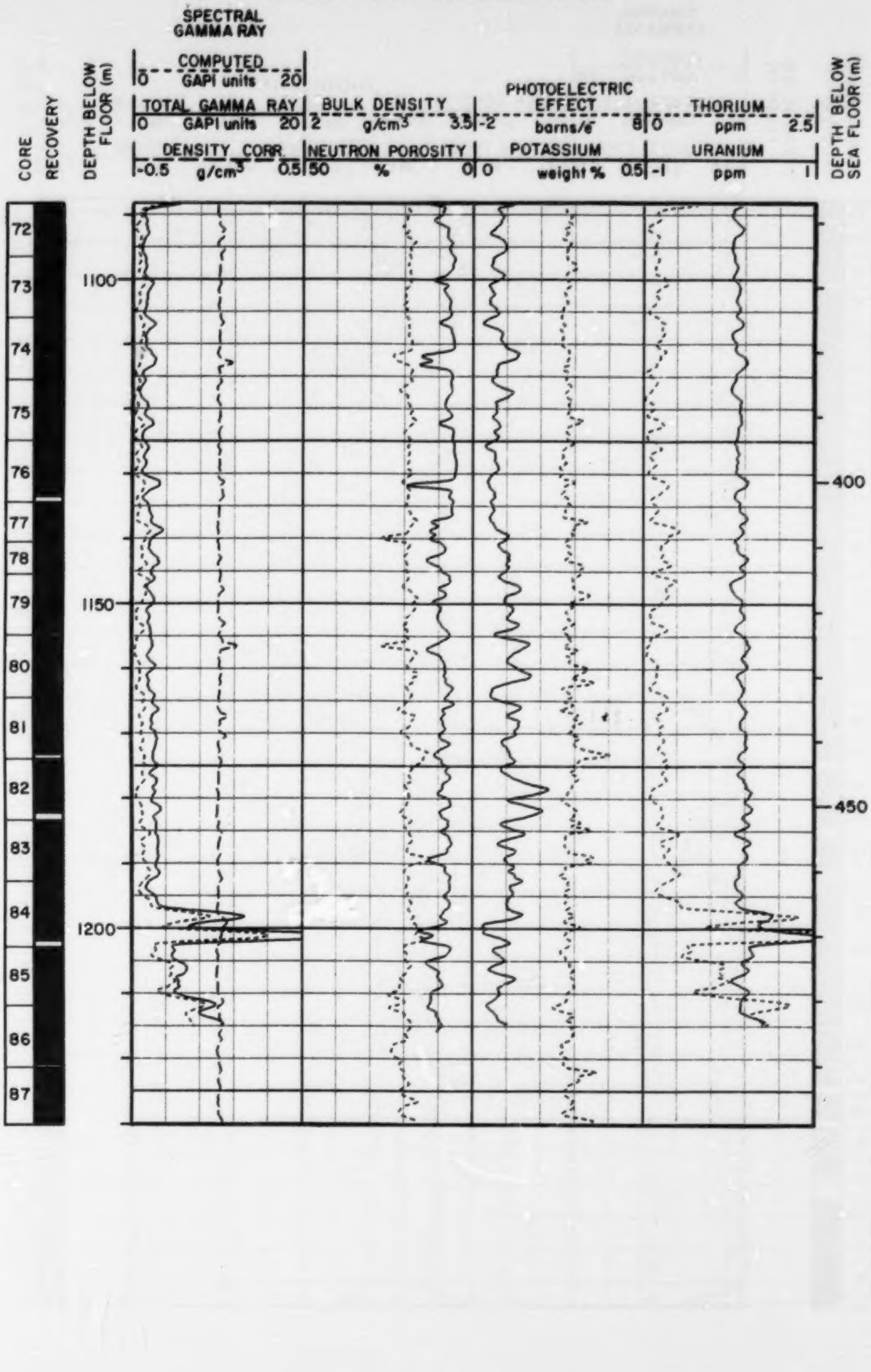
## Summary Log for Hole 735B (continued)



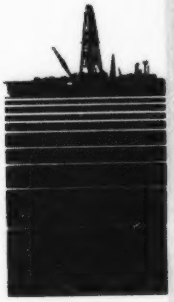
## Summary Log for Hole 735B (continued)



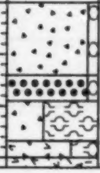
**Summary Log for Hole 735B (continued)**



# SECTION 3: CORES



SITE 732 HOLE B CORE 1D CORED INTERVAL 4878.3-4886.3 mbsl; 0.0-8.0 mbsf

| TIME-ROCK UNIT | BIOSTRAT. ZONE/ FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYS. PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLEISTOCENE | | NN 20-21 | | | | | | 1<br>2 | 0.5<br>1.0 |  | | TS | ● ● ● |

**LITHOLOGIC DESCRIPTION**

VOLCANIC SAND, MUDDY SILICEOUS OOZE, GRAVEL, SANDY CLAY, and BASALT PEBBLES

Core was forcibly extruded from barrel.

Major lithologies:

a. VOLCANIC SAND, very dark grayish brown (10YR 3/2), 90% of this interval, in Section 1, 0-70 cm.
   Medium-grained sand grading to coarse-grained sand. Composition is 90% volcanic sand fragments and <5% calcareous and siliceous microfossils. Volcanic sand is well-sorted; ~50% of grains are slightly rounded and 50% are angular to slightly rounded. MUDDY SILICEOUS OOZE, yellowish brown (10YR 5/4), 10% of this interval. 40 to 50% siliceous microfossils, <5% coccoliths, <5% broken foraminifers and 50% clay.

b. Clasts of GRAVEL and MUDDY SILICEOUS OOZE, plus distinct gravel pieces, in Section 1, 70-95 cm. GRAVEL is black (10YR 2/1), 1-2 cm diameter; weathered basalt and serpentinite, and subrounded. MUDDY SILICEOUS OOZE is yellowish brown (10YR 5/4).

c. SANDY CLAY, brown (10YR 5/3) to yellowish brown (10YR 5/4), with ~20-30% black volcanic gravel, 0.5-2.0 cm diameter; and ~10% coarse sand, very dark grayish brown (10YR 3/2), in Section 1, 95-135 cm.

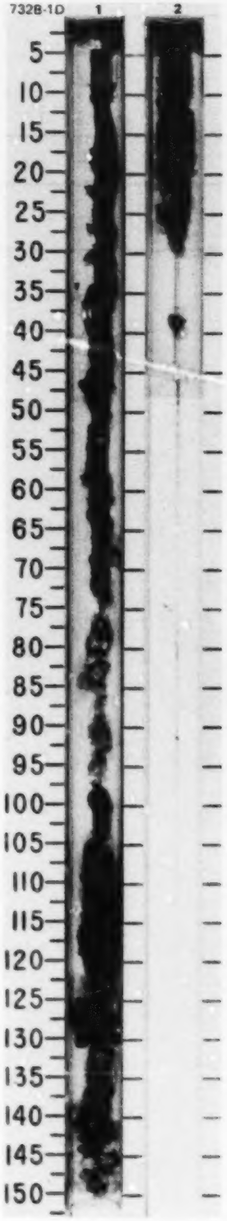
d. BASALT PEBBLES, black (10YR 2/1), 0.5-6.0 cm diameter, with ~30% very dark yellowish brown (10YR 5/4) MUDDY SILICEOUS OOZE, in Section 1, 135-150 cm. Largest clast is plagioclase-clinopyroxene-olivine phyric basalt. Olivine is totally oxidized; other clasts are weathered aphyric basalt.

e. PEBBLES, 1-3 cm diameter, angular to subangular, comprising 2 pieces of micro breccia (greenschist facies), 24 pieces of weathered basalt, 5 pieces of greenstone, 9 pieces of diabase, 1 piece of amphibolite gneiss, 21 pieces of gabbro (including 1 coarse-grained rodingtized gabbroic vein in serpentinite), and 20 pieces of serpentinite, in Section 2. 5 $cm^3$ of undifferentiated gravel (<1 cm diameter) to medium-grained sand. Representative pieces of each rock type are described seperately.

SMEAR SLIDE SUMMARY (%)

| | 1, 2<br>D | 1, 12<br>M | 1, 12<br>D | 1, 38<br>M |
|---|---|---|---|---|
| TEXTURE: | | | | |
| Sand | 80 | 15 | 95 | 5 |
| Silt | — | 5 | — | 5 |
| Clay | 20 | 80 | 5 | 90 |
| COMPOSITION: | | | | |
| Clay | 20 | 1 | 5 | 90 |
| Diatoms | — | 50 | — | 2 |
| Feldspar | — | 10 | 20 | — |
| Foraminifers | 5 | 5 | — | — |
| Nannofossils | — | 5 | — | 2 |
| Quartz | — | 5 | — | — |
| Radiolarians | — | Tr | 2 | — |
| Rock frag. | 75 | 5 | 75 | 5 |
| Silicoflag. | Tr | 2 | — | 1 |
| Spicules | — | 15 | — | — |

Information on Core Description Forms, for ALL sites, represents field notes taken aboard ship. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these forms with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.

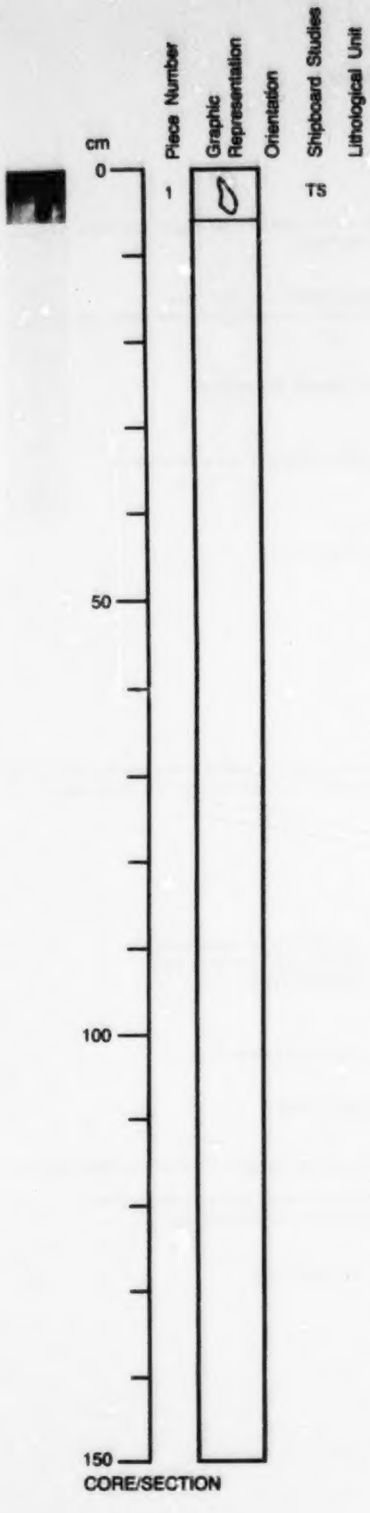


SITE 732 HOLE F CORE 2B CORED INTERVAL 4807.0-4822.8 mbsl; 0.0-15.8 mbsf

| TIME-ROCK UNIT | BIOSTRAT. ZONE/ FOSSIL CHARACTER | | | | PALEOMAGNETICS | PHYS. PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | | | | | | | | | | |
| PLEISTOCENE | | NN 20 | | | | | | CC | | | | | | DIATOM OOZE<br>Mud scraped from bit.<br>Major lithology: DIATOM OOZE, white (10YR 8/1), 2 x 5 cr diameter, fine grained, with 3 or 4 basalt chips, each <0.5 cm in length. |

SMEAR SLIDE SUMMARY (%):

| | CC, D |
|---|---|
| TEXTURE: | |
| Sand | 2 |
| Silt | 8 |
| Clay | 90 |
| COMPOSITION: | |
| Acc. min. | 2 |
| Foraminifers | 1 |
| Diatoms | 92 |
| Spicules | 5 |


cm
0
50
100
150
CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1
TS

## 118-732A-1D-1

### UNIT 1: RUBBLE

**Piece 1: Mylonite**

**COLOR:** Green-brown.

**LAYERING:** 1-5 mm, compositional, sequence cannot be determined (sample too small). Contact rather sharp between layers. Azimuth and dip cannot be determined, but are parallel to foliation.

**DEFORMATION:** Very strong mylonitic foliation, marked by flattened opaques. Lineation not visible. Azimuth and dip cannot be determined. Rotated augens indicate that simple shear was active during deformation. No variation in grain size visible.

**PRIMARY MINERALOGY:** Olivine, clinopyroxene(?), and oxides. Completely altered.

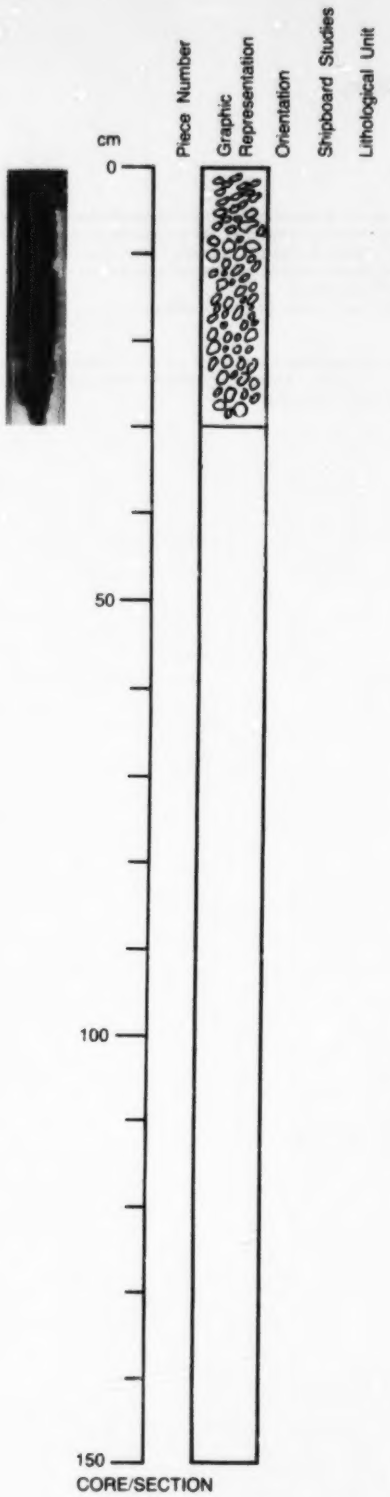
**SECONDARY MINERALOGY:**

Total percent: 100%.

Texture: Approximately 1-mm-thick layer of actinolite + mixture of amorphous oxides in a fine-grained smectite(?). Rotated augens of opaques + actinolite and chlorite. Flattened opaques with chlorite rims in a matrix of fine-grained serpentine(?).

Percent vein material: Not determined.

Vein material: Not determined.



**118-732B-1D-2**

## UNIT 2: GRAVEL*

### Type 1: Micro Breccia (2 pieces)

**GLASS:** Not determined.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Aphyric basalt grains and clasts, <2 mm, and albitized plagioclase clasts, <2 mm, are all subangular in a gray-green aphoritic matrix.
**COLOR:** Gray.
**VESICLES:** Not determined.
**STRUCTURE:** Massive, undeformed. Matrix supported breccia with 50% clasts.
**ALTERATION:** Moderately altered—replacement in clasts and matrix by chlorite, albite, and clay minerals.
**VEINS/FRACTURES:** None

### Type 2: Aphyric to Sparsely Plagioclase Phyric Basalt (24 pieces)

**GLASS:** None, no contacts.
**PHENOCRYST:** Single crystals.
Plagioclase—Trace (2-3%), 1-2 mm, subhedral, weathered, dull white surfaces.
**GROUNDMASS:** Microcrystalline.
**COLOR:** Gray. gray-brown, red-gray.
**VESICLES:** Rare. Less than 1 mm.
**STRUCTURE:** Rubble
**ALTERATION:** Weathered. Dull white plagioclase, altered to clays.
Groundmass also altered to clays.
**VEINS/FRACTURES:** None.

### Type 3: Metabasalt (5 pieces)

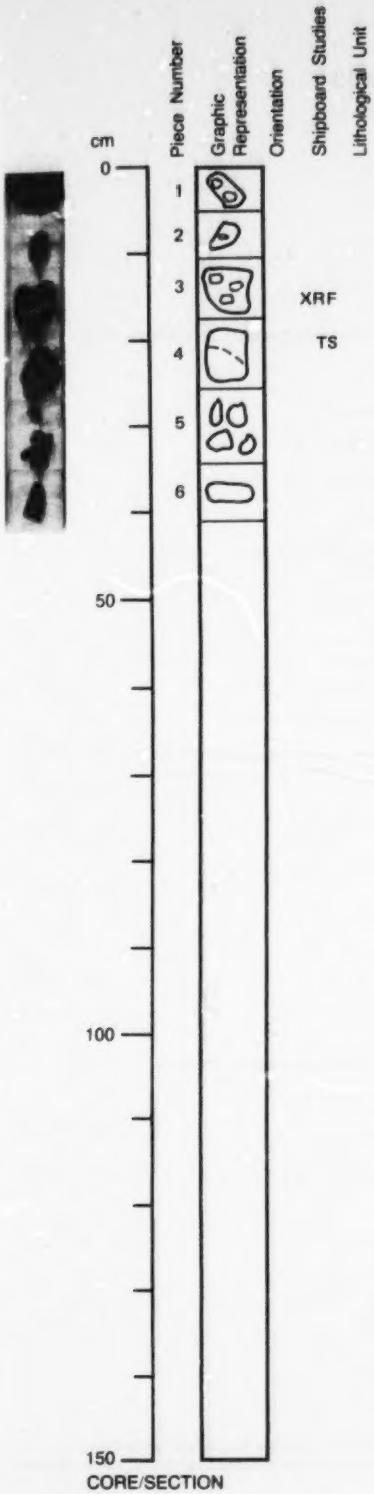
**GLASS:** None, no contacts.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Microcrystalline.
**COLOR:** Red, gray, gray-green.
**VESICLES:** None.
**STRUCTURE:** Rubble.
**ALTERATION:** Moderately to heavily altered—appear to be metabasalts. Secondary mineralogy inferred to be chlorite, albite, actinolite, and some clays. Probably more than 50% of the original rock is altered.
**VEINS/FRACTURES:** None.

### Type 4: Diabase (9 pieces)

**GLASS:** None, no contacts.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Fine-grained. Random orientation. Intersertal to intergranular texture.
Plagioclase—20-40%, less than 1 mm, euhedral, slightly altered to clays.
Clinopyroxene—30-40%, less than 1 mm, subhedral, fresh.
**COLOR:** Gray, gray-brown, brown-gray.
**VESICLES:** None.
**STRUCTURE:** Layering. Massive.
**ALTERATION:** Groundmass moderately altered to clays(?), and chlorite(?).
**VEINS/FRACTURES:** None.

### Type 5: Amphibolite Gneiss (1 piece—working half only)

**COLOR:** Layers of white and green-black.
**LAYERING:** <1-2 mm thick, discontinuous, lenticular alternating layers of fine-grained plagioclase and amphibole. Sharp contacts.
**DEFORMATION:** Foliation defined by phase layering. No lineation. Uniformly recrystallized.
**PRIMARY MINERALOGY:** Plagioclase and clinopyroxene—completely altered.
**SECONDARY MINERALOGY:**
Total percent: 100%.
Texture: <1 mm aggregates of amphibole and plagioclase.
Percent vein material: None.
Vein material: None.



**118-732C-2D-1**

**UNIT 1: RUBBLE**

**Pieces 1-6**

**Piece 1: Plagioclase Phyric Basalt**

**GLASS:** None, no contacts.
**PHENOCRYSTS:** Plagioclase—0.2-0.5 cm, partly altered.
**GROUNDMASS:** Fine-grained.
**COLOR:** Not determined.
**VESICLES:** None.
**STRUCTURE:** Rubble.
**ALTERATION:** Reddish oxide. Plagioclase phenocrysts partially altered.
**VEINS/FRACTURES:** Calcite vein coats part of one surface. No other veins.

**Piece 2: Sparsely Plagioclase Phyric Basalt**

**GLASS:** None, no contacts.
**PHENOCRYSTS:** Plagioclase.
**GROUNDMASS:** Very fine-grained.
**COLOR:** Not determined.
**VESICLES:** None.
**STRUCTURE:** Metabasalt(?).
**ALTERATION:** Red oxide. Two plagioclase phenocrysts have recrystallized rims.
**VEINS/FRACTURES:** None.

**Piece 3: Highly Plagioclase Phyric Basalt**

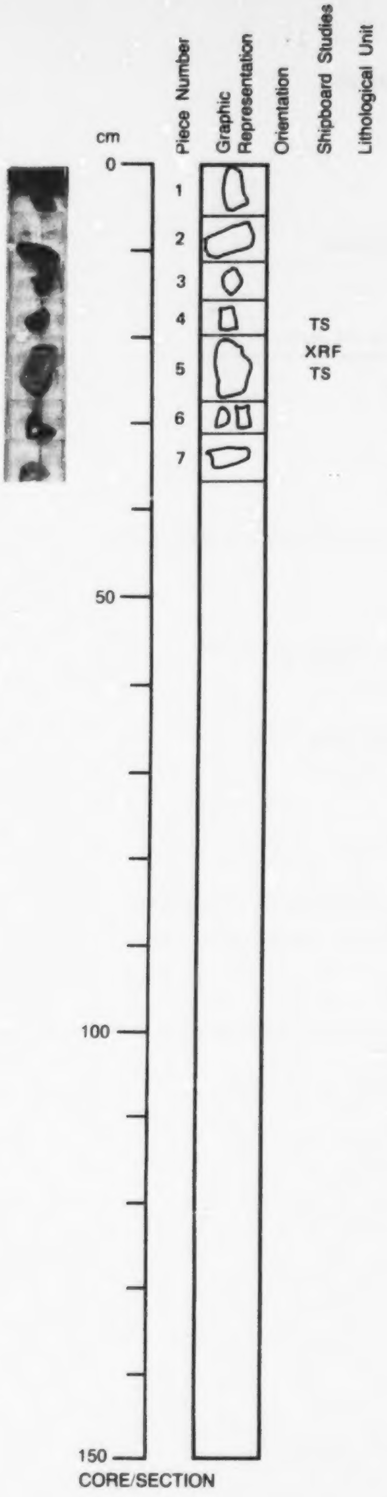
**GLASS:** None, no contacts.
**PHENOCRYSTS:** Plagioclase—10%, 0.2-0.5 cm, one megacryst 1 cm long.
**GROUNDMASS:** Fine-grained. Acicular plagioclase microlites.
**COLOR:** Dary gray, reddish tint.
**VESICLES:** None.
**STRUCTURE:** Not determined.
**ALTERATION:** Minor oxidative alteration to reddish oxides.
**VEINS/FRACTURES:** None.

**Piece 4: Aphyric Basalt**

**GLASS:** None, no contacts.
**PHENOCRYSTS:** <1% small plagioclase phenocrysts.
**GROUNDMASS:** Fine-grained, microlitic.
**COLOR:** Gray.
**VESICLES:** None, but some tiny, irregular cavities or pores can be seen.
**STRUCTURE:** Not determined.
**ALTERATION:** Faint reddish oxidative halo at one end, filling pore spaces in rock.
**VEINS/FRACTURES:** None.

**Pieces 5 and 6: Indurated Mafic Sandstone**

Cemented by iron-oxyhydroxides. Sand grains are polymict—basalt, plagioclase, serpentine, and more. Grains are quite angular but well sorted.



### 118-732C-3D-1

**UNIT 1: RUBBLE**

**Pieces 1-7**

**Piece 1: Aphyric Basalt**

No description.

**Piece 2: Gabbro**

**COLOR:** Not determined.
**LAYERING:** Massive.
**DEFORMATION:** Plagioclase locally deformed and crystal edges granulated. Sample cut by fractures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 68%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally deformed.
Percent replacement: 60% by clays and albite.

Clinopyroxene—Mode: 27%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: ~100% by amphibole with epidote.

Spinel—Mode: 5%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slightly altered to spinel.
**SECONDARY MINERALOGY:**
Total percent: ~70%.
Texture: Plagioclase, amphibole, clays, and epidote present.
Percent vein material: Not determined.
Vein material: Hematite/smectite vein. Also chlorite veins, chlorite + epidote veins, chlorite + epidote + amphibole veins, and epidote + amphibole + sphene veins.

**Piece 3: Sparsely Plagioclase Phyric Basalt**

No description.

**Piece 4: Metagabbro**

**COLOR:** Not determined.
**LAYERING:** Massive.
**DEFORMATION:** Mortar texture. Sample cut by fractures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 44%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: ~50% by chlorite, epidote, hornblende, and albite.

Clinopyroxene—Mode: 42%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: ~50% by chlorite, amphibole, and hornblende.

Spinel—Mode: 2%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 50%.

Hornblende—Mode: 2%.
Crystal size: <1 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: 50%.
**SECONDARY MINERALOGY:**
Total percent: ~60%.
Texture: Chlorite, epidote, hornblende, and albite replaces plagioclase. Albite forms an anastomosing network. Magnetite in pseudomorphs with amphibole. Clinopyroxene replaced by chlorite, amphibole, and hornblende.
Percent vein material: Not determined.
Vein material: Not determined.

## 118-732C-3D-1 (continued)

### Piece 5: Gabbroic Gneiss

**COLOR:** Not determined.
**LAYERING:** Gneissic.
**DEFORMATION:** Foliated. Sample cut by fractures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-10 mm.
Crystal shape: Porphyroblasts, crushed or locally recrystallized.
Preferred orientation: Not determined.
Percent replacement: ~50% by chlorite, epidote, and amphibole.

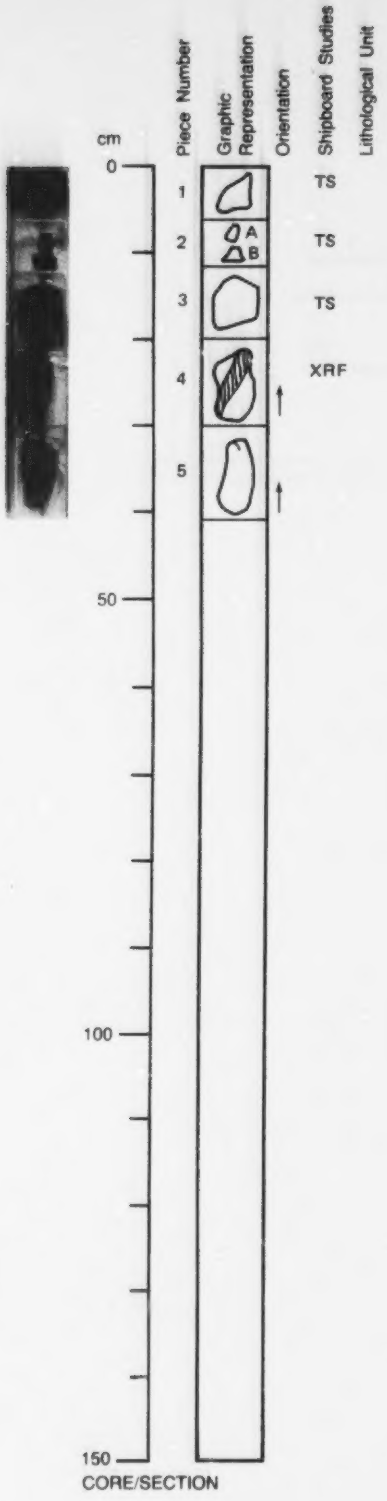
Green hornblende—Mode: 40%.
Crystal size: 1-10 mm.
Crystal shape: Porphyroblasts, kinked and recrystallized.
Preferred orientation: Not determined.
Percent replacement: ~25% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: ~55%.
Texture: Plagioclase is crushed and locally recrystallized into very small grains (<0.1 mm) or replaced by epidote-amphibole aggregates. Green hornblende replaced by amphibole. Epidote found in aggregates elongated in the foliation.
Percent vein material: Not determined.
Vein material: Epidote.

### Piece 6: Lithic Sandstone

No description.

### Piece 7: Aphyric Basalt

No description.



**118-732D-1D-1**

## UNIT 1: RUBBLE

**Pieces 1-5**

### Piece 1: Sparsely Plagioclase Phyric Basalt

**GLASS:** None, no contacts.
**PHENOCRYSTS:** Plagioclase—<0.2-0.5 cm.
**GROUNDMASS:** Fine-grained. Has two ~0.5 cm gabbroic(?) clots.
**COLOR:** Not determined.
**VESICLES:** ~2% filled by chlorite(?).
**STRUCTURE:** Rubble.
**ALTERATION:** Plagioclase phenocrysts partly altered to clays. Chlorite(?) replacing groundmass.
**VEINS/FRACTURES:** Veins of quartz, oxides, and chlorite(?).

### Piece 2A: Aphyric Basalt

No description.

### Piece 2B: Pyroxene Gabbro

**COLOR:** Not determined.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:** Plagioclase, pyroxene, and oxides. Very coarse-grained.
**SECONDARY MINERALOGY:** Clays and amphibole. Rock only slightly altered.

### Piece 3: Serpentinized Harzburgite

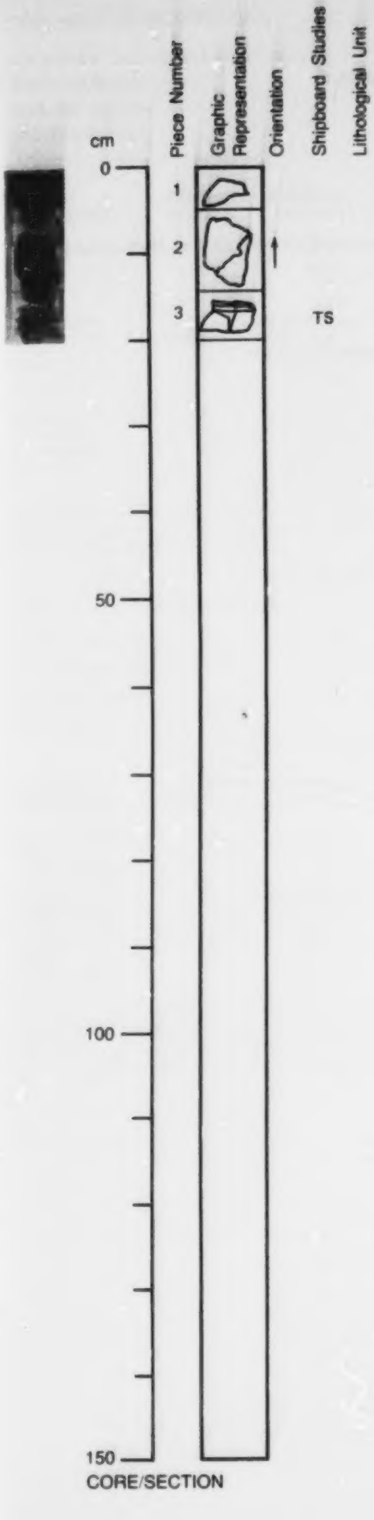
**COLOR:** Not determined.
**LAYERING:** Not determined.
**DEFORMATION:** Pyroxene elongation defines a rough foliation.
**PRIMARY MINERALOGY:** Olivine and pyroxene.
**SECONDARY MINERALOGY:** Serpentine. Rock is completely altered.

### Piece 4: Diabase with Basalt Dikelet

**GLASS:** Not determined.
**PHENOCRYSTS:** Plagioclase.
**GROUNDMASS:** Fine-grained. Plagioclase, pyroxene, and oxides.
**COLOR:** Gray.
**VESICLES:** None.
**STRUCTURE:** Not determined.
**ALTERATION:** Clays and amphibole.
**VEINS/FRACTURES:** 1 cm thick dikelet cuts sample.

### Piece 5: Plagioclase Phyric Basalt

No description.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CORE/SECTION

**118-732E-1R-1**

**UNIT 1: RUBBLE**

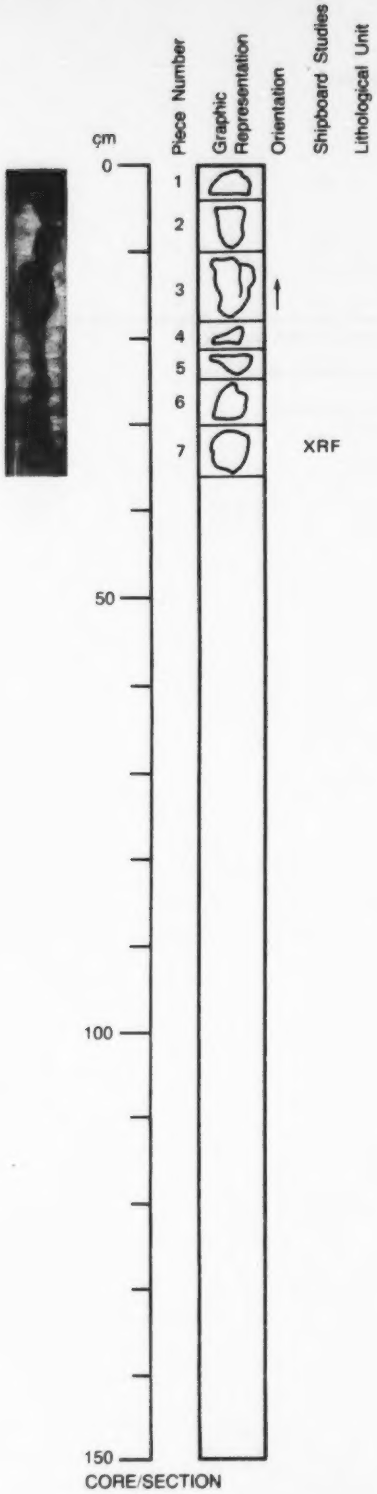
**Pieces 1-3**

**Pieces 1 and 2: Diabase**

No description.

**Piece 3: Highly Plagioclase Phyric Basalt**

**GLASS:** None, no contacts.
**PHENOCRYSTS:** Plagioclase—25%, 2-6 mm, euhedral, slightly altered to chlorite and prehnite.
**GROUNDMASS:** Fine- to medium-grained. Plagioclase, pyroxene, and opaques.
**COLOR:** Not determined.
**VESICLES:** Trace. Mostly filled by chlorite with minor prehnite and actinolite.
**STRUCTURE:** Rubble.
**ALTERATION:** Slightly altered to chlorite, actinolite, and prehnite.
**VEINS/FRACTURES:** Veins of zeolite(?) and chlorite(?).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CORE/SECTION

**118-732F-1R-1**

## UNIT 1: RUBBLE

**Pieces 1-7**

### Piece 1: Moderately Olivine Phyric Basalt

**GLASS:** None, no contacts.
**PHENOCRYSTS:** Homogeneous distribution. Olivine, 3-5%, 0.5 mm, subhedral, 100% altered to clay minerals.
**GROUNDMASS:** Microcrystalline.
**COLOR:** Dark gray.
**VESICLES:** None.
**STRUCTURE:** Rubble.
**ALTERATION:** Slightly altered. Olivine 100% altered to clay minerals.
**VEINS/FRACTURES:** None.

### Pieces 2, 3, 5, and 6: Aphyric Diabase

**GLASS:** None, no contacts.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Fine-grained.
**COLOR:** Dark gray.
**VESICLES:** None.
**STRUCTURE:** Rubble.
**ALTERATION:** Slightly altered.
**VEINS/FRACTURES:** Piece 3: Oxidation halo along empty(?) fracture.

### Pieces 4 and 7: Aphyric Basalt

**GLASS:** None, no contacts.
**PHENOCRYSTS:** None.
**GROUNDMASS:** Fine-grained.
**COLOR:** Gray.
**VESICLES:** None.
**STRUCTURE:** Rubble.
**ALTERATION:** Fresh.
**VEINS/FRACTURES:** Small fracture in each piece.

## THIN SECTION DESCRIPTION

**118-732A-1D-1 (Piece 1, 0-2 cm)**

**ROCK NAME:** Serpentinized peridotite/mylonite

**WHERE SAMPLED:** Rubble

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 75 | | | | Fine-grained aphanitic. Completely altered to serpentine. |
| Pyroxene | — | (?) | | | | |
| Spinel | — | Tr | 0.1–0.5 | Ferric chromite | | Chromite now altered to ferric chromite with chlorite rims. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | Ol(?), amphibole | Honey colored mineral. Very fine-grained. Represents possible alteration of relict ol or amphibole. Coarser amphibole is stained brown suggesting that the honey-colored mineral is partially replacing amphibole rims. |
| Chlorite | Tr | Chromite | Rims around ferric chromite (which has replaced spinel). |
| Serpentine | 80 | Ol, px | |
| Amphibole(?) | 10 | Px(?) | Identification questionable, possibly smectite. Typically very fine-grained. Defines foliation. |
| Magnetite | 5 | Ol, px | Anhedral. Intergrown with serpentine. |

**COMMENTS:** Fine-grained mylonite. Occasional augen consist of serpentine after px + ferric chromite after spinel. Amphibole(?) schileren also present; probably represent a replacement of smeared out primary px. Foliation defined by amphibole(?) laths, schlieren, serpentine replacing oriented, elongated ol crystals, and rotated serpentine sheaves.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 5-6 cm)**

**ROCK NAME:** Gabbro gneiss

**WHERE SAMPLED:** Rubble

**TEXTURE:** Gneissic

**GRAIN SIZE:** Fine

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Clinopyroxene | 30 | (?) | 0.25 | | Granular | Cores are replaced. |
| Spinel | 2 | 2 | | | Anhedral | |
| Orthopyroxene | Tr | 8 | | | | Corroded. Relict igneous crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 50 | Plag | Crystal size ranges 0.1–0.3 mm. Granular texture. Metamorphic, recrystallize. |
| Bastite | 8 | Opx | Fine-grained. Replacing cpx cores. |
| Hornblende | 10 | Cpx | Brown. |

**COMMENTS:** Most of the cpx could be metamorphic.
Two stages of deformation: 1)recrystallization of plag + cpx, granulite facies; 2)replacement of opx by bastite.
Cpx is recrystallized during deformation, but not opx.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 6-7 cm)**

**ROCK NAME:** Diabase

**WHERE SAMPLED:** Rubble

**TEXTURE:** Subophitic

**GRAIN SIZE:** Medium

**OBSERVER:** STA, CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 50 | L(max) = 3.5<br>W(max) = 1.0 | | Subhedral | Clear sodic rims. Locally replaced by actinolite. |
| Clinopyroxene | 20 | 30 | L(max) = 1.5<br>W(max) = 1.0 | | Subhedral | Replaced by clay and epidote. |
| Magnetite | 10 | 10 | <0.5 | | Subhedral | Fresh. |
| Olivine | — | 10 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Ol | Fe-stained smectites. |
| Chlorite | 2 | Plag | Pale, blue interference colors. |
| Epidote | 10 | Cpx | Yellow, very small grains. |
| Actinolite | 8 | Plag | Acicular. |

**COMMENTS:** Greenschist facies overprint.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 7-8 cm)**

**ROCK NAME:** Aphyric diabase

**WHERE SAMPLED:** Rubble

**TEXTURE:** Equigranular, holocrystalline

**GRAIN SIZE:** Fine

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 50 | 0.1–0.6 | | Anhedral, blocky | Replaced by clays. Dusty appearance. |
| Clinopyroxene | 23 | 23 | 0.15–0.25 | | Anhedral, equant | |
| Oxides | 7 | 7 | 0.05–0.15 | Fe-Ti | Anhedral, equant | |
| Olivine | — | 20 | | | | Replaced by clay. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Plag | Occurs along veins and cracks. |
| Clays | 20 | Ol | Brown. Interstitial. Replaces ol. |

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 8-9 cm)**

**ROCK NAME:** Serpentinite

**WHERE SAMPLED:** Rubble

**TEXTURE:** Mesh texture

**GRAIN SIZE:**

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Clinopyroxene | 2 | (?) | | | | Partially replaced by serpentine. |
| Spinel | Tr | Tr | | Chromian | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Magnetite | 2 | | |
| Serpentinite | 96 | | Bastite. Replaces all primary phases. |

**COMMENTS:** Possibly after peridotite.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 9-10 cm)**

**ROCK NAME:** Vein from metagabbro(?)
**WHERE SAMPLED:** Rubble
**TEXTURE:** No longer apparent.
**GRAIN SIZE:** Coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Plagioclase | — | (?) | | | |
| Clinopyroxene | — | 5(?) | | | |
| Orthopyroxene | 1 | 1 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 4 | Px | Colorless. Replaces cpx(?). Forms whiskers on cpx pseudomorphs. |
| Prehnite | 90 | Plag(?) | Ghost outlines of plag and plag twins in prehnite. |
| Serpentine | 5 | | |

**COMMENTS:** This rock is composed totally of secondary minerals. Primary texture and most primary mineralogy is no longer apparent. Orthopyroxene is the only primary mineral remaining. Cpx pseudomorphs are composed of actinolite + serpentine.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 10-11 cm)**

**ROCK NAME:** Aphyric basalt
**WHERE SAMPLED:** Rubble
**TEXTURE:** Intergranular
**GRAIN SIZE:** Microcrystalline
**OBSERVER:** STA, CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 40 | <0.1 | | Euhedral, laths | Extensively altered to colorless clay. |
| Clinopyroxene | 30 | 30 | <0.1 | | Euhedral, laths | Partially altered to Fe-stained clays. |
| Magnetite | 10 | 10 | 0.01 | | Subhedral | Fresh. |
| Glass | — | 10 | | | | Altered to clay. |
| Olivine | — | 10 | | | | Replaced by red Feoxyhydroxide + clay(?) |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 30 | Plag, ol, glass | Fe-stained clay replacing cpx. Clay (smectite?) also replaces an inclusion(?) in a magnetite crystal. |

**COMMENTS:** Low temperature oxidation.

## THIN SECTION DESCRIPTION

**118-732B-1D-2 (Piece 1, 11-12 cm)**

**ROCK NAME:** Metagabbro
**WHERE SAMPLED:** Rubble
**TEXTURE:** Holocrystallin
**GRAIN SIZE:** Coarse
**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 80 | >3 | | Euhedral | Cut extensively by veins. |
| Clinopyroxene | 10 | 18 | 3 | | Euhedral | Amphibole pseudomorphs after cpx. |
| Spinel | 2 | 2 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 2 | Plag(?) | |
| Albite | 30 | Plag(?) | |
| Epidote | 10 | Veins | Filling veins in cpx. One large vein through plag. |
| Actinolite | 5 | Plag, cpx | |

**COMMENTS:** Feldspar percentages based on the following distinctions: plag, twinned cores; albite, clear pseudomorphs or turbid regions due to epidote inclusions.
One large vein of clinozosite(?).
Grains are crushed, but not deformed.

## THIN SECTION DESCRIPTION

**118-732C-2D-1 (Piece 3, 14-17 cm)**

**ROCK NAME:** Moderately plagioclase phyric basalt

**WHERE SAMPLED:** Rubble

**TEXTURE:** Porphyritic

**GRAIN SIZE:** Fine

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | — | 1 | 1.0-1.2 | | Subhedral | Microphenocrysts. Altered to clays. |
| Plagioclase | 4 | 4 | 0.5-6.0 | | Subhedral | Skeletal overgrowths. Zoned and twinned crystals. Altered to clays. |
| GROUNDMASS | | | | | | |
| Plagioclase | 40 | 45 | 0.1-0.5 | | Subhedral | Quench overgrowths. |
| Clinopyroxene | 10 | 10 | <0.1 | | Subhedral | Occurs in interstices of plag crystals. |
| Olivine | — | 8 | 0.1-0.2 | | Subhedral, skeletal | Altered to clays and red mineral (oxide?). |
| Cryptocrystalline groundmass | 30 | 30 | <0.1 | | | Unidentified groundmass. |
| Oxides | 1 | 1 | <0.1 | | Subhedral | Elongate habit, acicular. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Filling thin cracks and veinlets in phenocrysts. |
| Clays | 13 | Ol, plag | Substantial replacement of groundmass ol. Local replacement of groundmass plag. |
| Zeolites | 1 | | Spherical morphology. Replaces some ol. |
| Chlorite | 1 | Ol | |

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## THIN SECTION DESCRIPTION

**118-732C-2D-1 (Piece 4, 19-21 cm)**

**ROCK NAME:** Aphyric basalt

**WHERE SAMPLED:** Rubble

**TEXTURE:** Microporphyritic

**GRAIN SIZE:** Microcrystalline

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | — | 1 | 0.25-0.50 | | Subhedral, skeletal | Totally replaced by calcite. |
| Plagioclase | 10 | 20 | 0.5-1.0 | | Subhedral, skeletal | Partially altered to albite(?) + clays. |
| Clinopyroxene | <1 | <1 | 0.25 | Augite | Anhedral | |
| GROUNDMASS | | | | | | |
| Plagioclase | 49 | 50 | ≈0.5 | | Skeletal, sheaves | Quench texture. |
| Cryptocrystalline groundmass | 23 | 23 | | | | Unidentified mineralogy. |
| Oxides | 1 | 1 | <0.01 | Magnetite(?) | Anhedral, equant | |
| Clinopyroxene | 5 | 5 | <0.2 | Augite | Anhedral | Interstitial between plag sheaves. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Clays | 1 | Plag |
| Carbonate | 1 | Ol |
| Albite | 10 | Plag |

**COMMENTS:** Rapidly cooled basalt with quench crystallization textures.

## THIN SECTION DESCRIPTION

**118-732C-3D-1 (Piece 2, 5-10 cm)**

**ROCK NAME:** Metagabbro
**WHERE SAMPLED:** Rubble
**TEXTURE:** Holocrystalline
**GRAIN SIZE:** Coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 68 | 5–10 | | Anhedral | Dusty appearance. Altered to clays + albite. |
| Clinopyroxene | Tr | 27 | 5–10 | | Anhedral | Completely replaced by amphibole ± epidote |
| Spinel | 3 | 5 | 2–4 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 13 | Veins | Also in large patches in between granulated plag. |
| Albite | 20 | Plag | Replaces plag in a network fashion associated with chlorite and epidote |
| Epidote | 15 | Veins, plag | |
| Actinolite | 27 | Cpx, veins | Green to yellow pleochroism. |
| Sphene | 2 | Fe-Ti oxides | |

**COMMENTS:** Plag locally deformed and crystal edges granulated (incipient mortar texture).
Veins include chlorite, chlorite + epidote, chlorite + epidote + amphibole, epidote + amphibole + sphene
Xenolith(?) quench basalt on margin.

## THIN SECTION DESCRIPTION

**118-732C-3D-1 (Piece 4, 15-18 cm)**

**ROCK NAME:** Metagabbro
**WHERE SAMPLED:** Rubble
**TEXTURE:** Mortar
**GRAIN SIZE** Very coarse
**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 51 | 2–6 | | Anhedral | |
| Clinopyroxene | 20 | 45 | 3–5 | | Anhedral | |
| Spinel | 1 | 2 | | | Anhedral | |
| Hornblende | 1 | 2 | <1 | | Anhedral | Red-brown. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 5 | Plag | |
| Albite | 5 | Plag | Anastomosing pattern. |
| Epidote | 1 | Plag | Epidote + chlorite replaces plag. |
| Actinolite | 15 | Cpx, hbd, plag | Occurs with chlorite, along plag-cpx boundaries. |
| Hornblende | 10 | Plag, cpx | Green and brown. |
| Plagioclase | 20 | Plag | Granular. Mortar structure |
| Prehnite | 1 | Plag | |
| Magnetite | 1 | Spinel | In pseudomorphs with amphibole. |

## THIN SECTION DESCRIPTION

**118-732C-3D-1 (Piece 5, 20-23 cm)**

**ROCK NAME:** Foliated metagabbro
**WHERE SAMPLED:** Rubble
**TEXTURE:** Porphyroclastic
**GRAIN SIZE:** Fine to coarse
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 60 | 1–10 | | | |
| Hornblende | 30 | 40 | 1–10 | | | Green. Partially recrystallized. Kinked crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite(?) | 15 | Plag, hbd | Composition could be an actinolitic hornblende. |
| Plagioclase | 25 | Plag | Some porphyroclasts. Crushed or locally recrystallized in very small grains or in an epidote + actinolite aggregate. |
| Chlorite | <1 | Plag | |
| Epidote | 30 | Plag | Found in aggregates defining foliation and in the crosscutting veins. |

**COMMENTS:** The gabbro was first metamorphosed in the green hbd + plag facies. The crushing deformation developed in the actinolite or actinolitic hbd + plag + epidote facies.
Epidote crystallization in veins continued after deformation.

## THIN SECTION DESCRIPTION

**118-732D-1D-1 (Piece 1, 0-5 cm)**

**ROCK NAME:** Sparsely plagioclase phyric basalt

**WHERE SAMPLED:** Rubble

**TEXTURE:** Porphyritic, vesicular

**GRAIN SIZE:** Fine

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Plagioclase | 1 | 2 | 0.5–2.5 | | Anhedral | Large patches altered to chlorite + epidote. |
| GROUNDMASS | | | | | | |
| Plagioclase | 45 | 50 | 0.1–0.6 | | Skeletal, acicular | Sheaf texture. |
| Clinopyroxene | 25 | 25 | <0.1 | | Anhedral | Pinkish-brown color. Intersertal texture. |
| Oxides | 1 | 1 | <0.01 | Fe-Ti | Anhedral, equant | |
| Olivine | — | 22 | | | | Completely replaced by chlorite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 23 | Ol, plag. | Also fills vesicles and veins. |
| Epidote | 2 | Plag, veins | Occurs with chlorite in veins. |
| Quartz | 2 | Plag, veins | Occurs with epidote, replacing plag. Deformed during vein filling. |
| Oxides | 1 | Veins | Fe-Ti oxides. Yellowish brown to red oxides. Occurs with chlorite in veins. |

| VESICLES/ CAVITIES | PERCENT | LOCATION | SIZE RANGE (mm) | FILLING | SHAPE | COMMENTS |
|---|---|---|---|---|---|---|
| Vesicles | 2 | Even | 1 | Chlorite | Round | Filled by chlorite. |

**COMMENTS:** Difficult to determine how much matrix has been altered due to greenschist facies metamorphism. Phenocrysts and microphenocrysts may be albitized.

## THIN SECTION DESCRIPTION

**118-732D-1D-1 (Piece 2B, 7-9 cm)**

**ROCK NAME:** Ferrogabbro

**WHERE SAMPLED:** Rubble

**TEXTURE:** Orthocumulate

**GRAIN SIZE:** Very coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 25 | 30 | <10 | | | |
| Clinopyroxene | 25 | 30 | 2–5 | | | Replaced by actinolite. |
| Spinel | 20 | 20 | 3–8 | | | |
| Orthopyroxene | 5 | 10 | | | Anhedral | Replaced by serpentine + magnetite. |
| Hornblende | 7 | 10 | | | Anhedral | Brown. Late, intercumulus. |
| Apatite | Tr | | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Serpentine | 5 | Opx(?) |
| Clays | 3 | Hbd |
| Actinolite | 10 | Hbd, plag, px |

## THIN SECTION DESCRIPTION

**118-732D-1D-1 (Piece 3, 12-18 cm)**

**ROCK NAME:** Serpentinized harzburgite
**WHERE SAMPLED:** Rubble
**TEXTURE:** Porphyroclastic
**GRAIN SIZE:** Coarse
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 70 | | | | Completely altered to serpentine. Coarse mesh texture. |
| Spinel | Tr | 1 | 1 | | Lobate | Altered to magnetite. Partially plucked during polishing. |
| Pyroxene | — | 29 | 1–5 | | | Bastite pseudomorphs after both opx and cpx. Difficult to distinguish between the two px pseudomorphs; rough estimation 25% opx, 5% cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Serpentine | 98 | Ol, px | Bastite pseudomorphs after both opx and cpx. |
| Magnetite | 2 | Ol, spinel | Occurs as rims around spinel and as scattered grains in serpentine after ol |

**COMMENTS:** Elongation of px aggregates defines a rough foliation.

## THIN SECTION DESCRIPTION

**118-732D-1D-1 (Piece 4, 21-25 cm)**

**ROCK NAME:** Moderately plagioclase phyric basalt
**WHERE SAMPLED:** Rubble
**TEXTURE:** Subophitic, intersertal
**GRAIN SIZE:** Fine
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Plagioclase | 5:5 | 5:5 | | | Euhedral | One large crystal in host. One crystal in dike. Crystal in dike may be originally from host rock ( based on cpx and opaque inclusions). Amphibole ± epidote ± albite occur along rectilinear fractures in the plag. |
| GROUNDMASS | | | | | | |
| Clinopyroxene | 32:30 | 32:30 | 0.1–0.4 | | Anhedral | |
| Plagioclase | 39:43 | 42:45 | 0.3–1.0 | | Subhedral | Pronounced alignment in host. |
| Spinel | 4:10 | 4:10 | 0.05–1.00 | | Anhedral | Skeletal crystals occur in dikelet. |
| Mesostasis | 0:0 | 17:10 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3(?):0 | Mesostasis | Probably smectite. |
| Chlorite | 1:2 | Mesostasis | |
| Albite | 1:2 | Plag | Occurs along fractures in plag. |
| Actinolite | 15:8 | Mesostasis | Pale green patches after mesostasis. Also in fractures in plag. |

**COMMENTS:** 1 cm dike cuts sample (constitutes approximately 20% of the slide). Percentages refer to ROCK:DIKE estimates. Dike has higher percentage of opaques, and is generally finer-grained (0.1 mm average grain size). Dike has a fine-grained border on one side that looks like recrystallized host rock (equigranular, 0.02–0.05 mm grain size).

## THIN SECTION DESCRIPTION

**118-732E-1R-1 (Piece 3, 17-20 cm)**

**ROCK NAME:** Highly plagioclase phyric diabase

**WHERE SAMPLED:**

**TEXTURE:** Porphyritic, ophitic

**GRAIN SIZE:** Medium

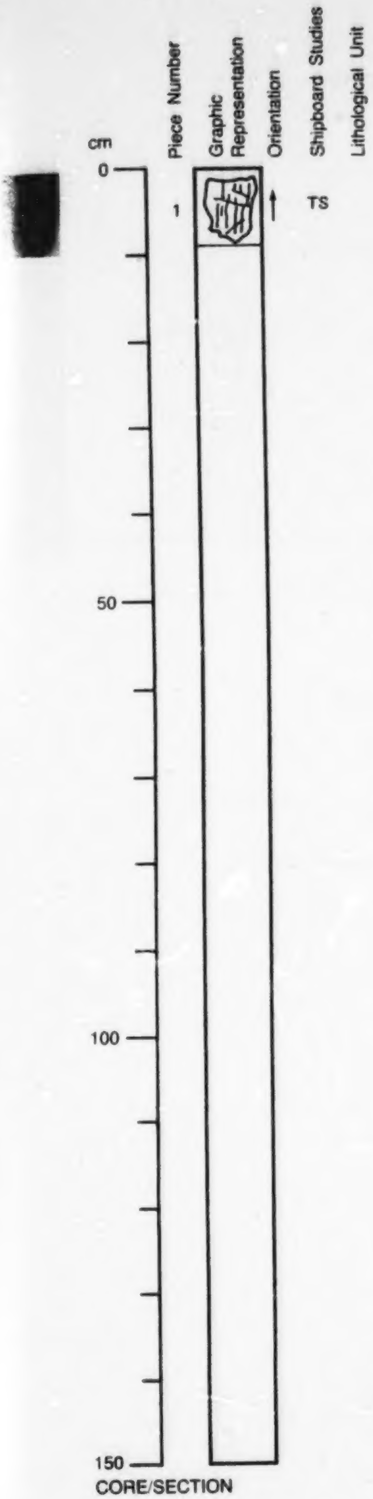
**OBSERVER:** MEY, STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Plagioclase | 51 | 55 | 2-6 | | Euhedral | Homogeneous cores. Narrow, strongly zoned rims. Altered melt inclusions in cores. |
| Spinel | Tr | Tr | <0.1 | Chromian | Euhedral | Inclusions in plag. |
| GROUNDMASS | | | | | | |
| Plagioclase | 22 | 30 | 0.4-1.0 | | Anhedral | Small oikocrysts ophitically enclose plag. |
| Oxides | 2 | 2 | 0.1-0.4 | Fe-Ti | Subhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 7 | Plag, veins | |
| Actinolite | 5 | Plag, cpx | Also in interstitial areas. |
| Prehnite | 3 | Plag, veins | |

| VESICLES/CAVITIES | PERCENT | LOCATION | SIZE RANGE (mm) | FILLING | SHAPE | COMMENTS |
|---|---|---|---|---|---|---|
| Vesicles | Tr | | 1.0 | Chlorite ± prehnite ± actinolite | Spherical | One vesicle. Mostly filled with chlorite except for small interior spheres of prehnite. |

**COMMENTS:** Percentages based on 750 point counts.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1
TS
50
100
150
CORE/SECTION

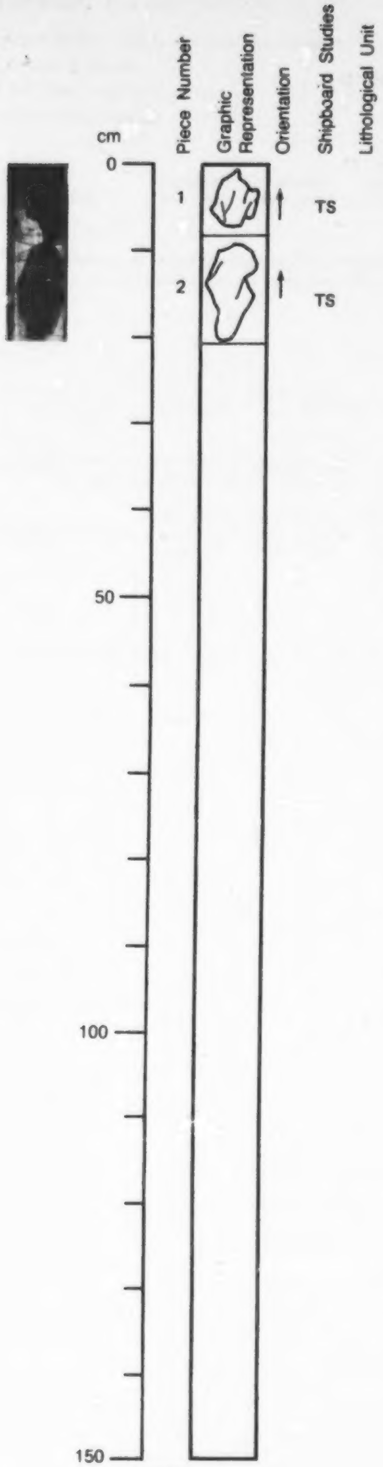
## 118-733B-1D-1

### UNIT 1: RUBBLE

**Piece 1**

**Piece 1: Metagabbro-Amphibolite**

**COLOR:** Gray green.
**LAYERING:** None.
**DEFORMATION:** Lineation defined by elongate plagioclase porphyroclasts and by alignment of amphibole grains and clots. Plagioclase porphyroclasts, 2-4 mm. Amphibole 2 mm to very small grains.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Not determined.
Crystal size: 1-3 mm.
Crystal shape: In porphyroclasts.
Preferred orientation: In lineation.
Percent replacement: 90% by albite and epidote(?).
**SECONDARY MINERALOGY:**
Total percent: 95%.
Texture: Lineated amphibole about 70%. Plagioclase porphyroclasts with fine intergranular albite or plagioclase—really a tectonite fabric. Probably some chlorite, maybe epidote.
Percent vein material: 2%.
Vein material: <1 mm veins cutting lineation. Possibly contain prehnite(?).
**COMMENTS:** The rock is completely recrystallized except for plagioclase. There is a tectonite fabric. The rock was probably a pyroxene gabbro.



## 118-733C-1D-1

### UNIT 1: RUBBLE

### Pieces 1 and 2

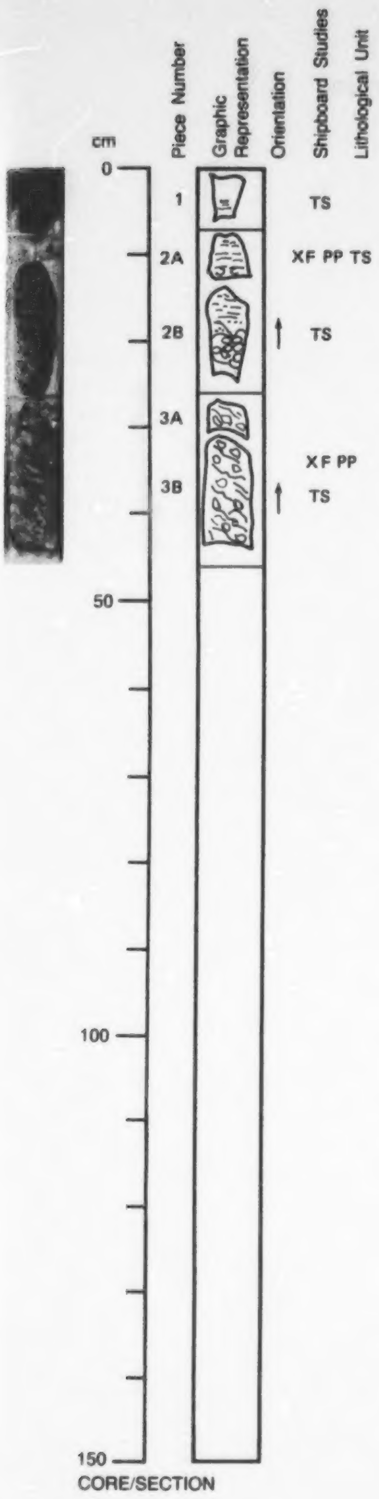
### Piece 1: Metabasalt/Amphibolite

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: 1%.
  Crystal size: 1-1.5 mm.
  Crystal shape: Euhedral.
  Preferred orientation: None.
  Percent replacement: Fresh.

  Clinopyroxene—Mode: 1%.
  Crystal size: 1 mm.
  Crystal shape: Subhedral.
  Preferred orientation: None.
  Percent replacement: Altered to amphibole.
**SECONDARY MINERALOGY:**
  Total percent: 50%.
  Texture: Amphibole replaces clinopyroxene and groundmass, particularly along thin veins.
  Percent vein material: Not determined.
  Vein material: Not determined.
**COMMENTS:** Primary mineralogy: Plagioclase and clinopyroxene as phenocrysts.

### Piece 2: Foliated Metagabbro

**COLOR:** Dark gray.
**LAYERING:** Not determined.
**DEFORMATION:** Well developed foliation dipping at 28°.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: Not determined.
  Crystal size: 0.5-1 cm porphyroclasts.
  Crystal shape: Anhedral.
  Preferred orientation: Not determined.
  Percent replacement: Fresh(?).
**SECONDARY MINERALOGY:**
  Total percent: Not determined.
  Texture: Secondary minerals are amphibole and feldspar.
  Percent vein material: Not determined.
  Vein material: Amphibole.
**COMMENTS:** Rock is medium-grained.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2A
2B
3A
3B
TS
XF PP TS
TS
XF PP
TS
CORE/SECTION

## 118-733D-1D-1

**UNIT 1: GNEISS**

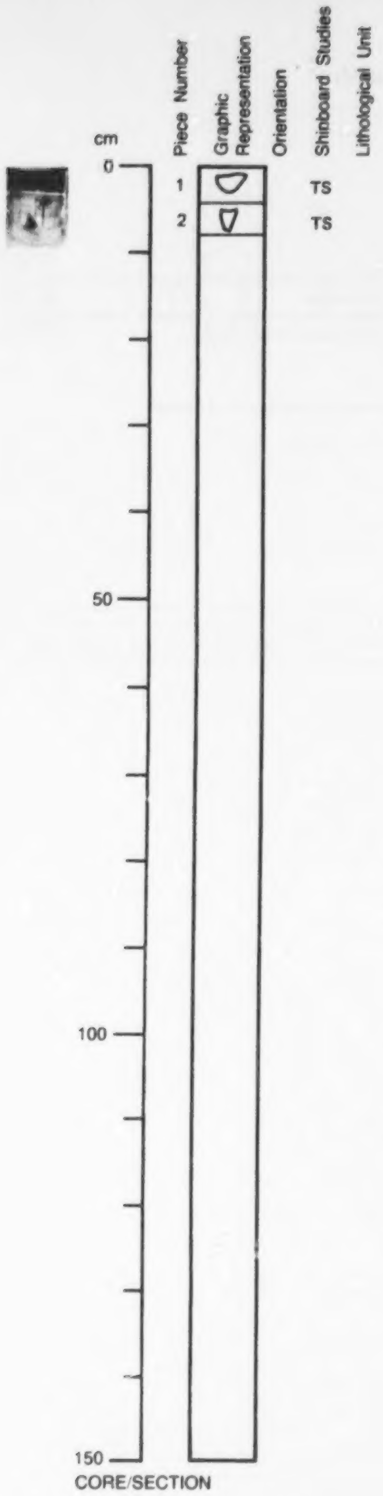
**Pieces 1-3B**

**Medium-Grained Gneiss**

**Pieces 1-3B**

**COLOR:** Gray.
**LAYERING:** Piece 1 is medium-grained. Pieces 2A and 2B form a transition to more coarse-grained gneissic textures developed in Pieces 3A and 3B.
**DEFORMATION:** Foliation dips at 44° from horizontal. Fabric consists of numerous pyroxene(?) augen in a matrix of feldspar forming a well developed gneissic texture.
**PRIMARY MINERALOGY:**
Feldspar—Mode: 60%.
Crystal size: Not determined.
Crystal shape: Highly deformed, occasional euhedral augen are present.
Preferred orientation: Not determined.
Percent replacement: Cloudy white—may be altered.

Pyroxene—Mode: 40%.
Crystal size: 1-10 mm.
Crystal shape: Augen.
Preferred orientation: Not determined.
Percent replacement: Chlorite or actinolite rims.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Black veins, 0.2 mm thick, inclined at 60° from subhorizontal and subparallel to mineral foliation in Pieces 3A and 3B are filled with chlorite or actinolite. Piece 2B: Thin white vein, 0.3 mm thick crosses the sample at about 15° from horizontal. Pyroxene augen appear to have chloritic rims (or actinolite). Feldspar appears cloudy white and may be altered.


cm
Piece Number
Graphic Representation
Orientation
Shinboard Studies
Lithological Unit
0
1
2
TS
TS
50
100
150
CORE/SECTION

118-733D-2D-1

**UNIT 2: RUBBLE**

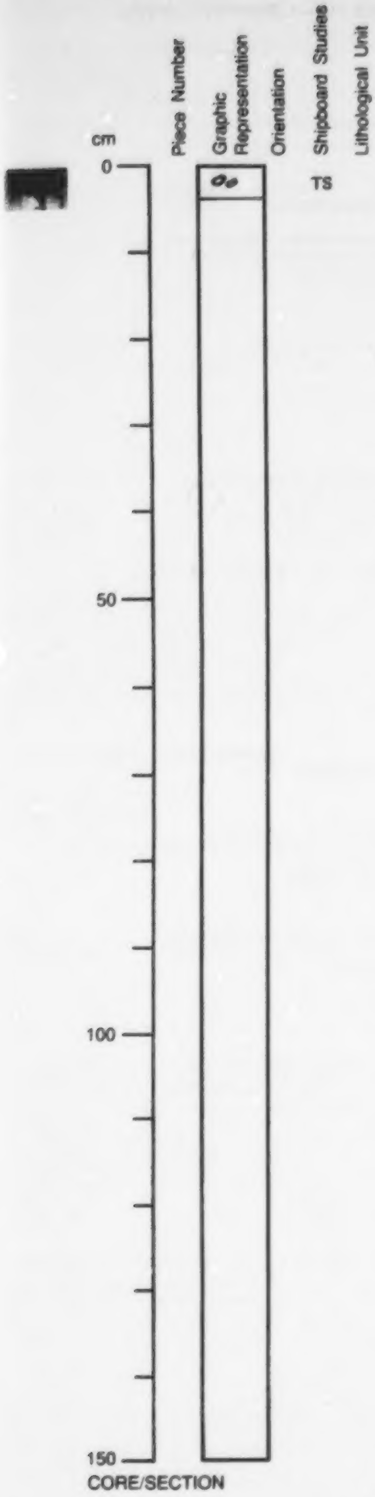
**Pieces 1 and 2**

**Piece 1: Foliated Metagabbro**

No description.

**Piece 2: Foliated Amphibolite**

No description.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
TS
50
100
150
CORE/SECTION

**118-733D-3B-1**

**UNIT 2: RUBBLE**

**Piece 1**

**Piece 1: Chlorite-Serpentinite Chips**

**COLOR:** Gray green.
**LAYERING:** None.
**DEFORMATION:** Weakly foliated—defined by chlorite alignment.
**PRIMARY MINERALOGY:** None, completely replaced.
**SECONDARY MINERALOGY:**
Total percent: 100%.
Texture: Chlorite-serpentine—no percentages can be determined. Orange surface staining.
Percent vein material: Not determined.
Vein material: Not determined.

## THIN SECTION DESCRIPTION

**118-733B-1D-1 (Piece 1, 1-4 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM/CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 50 | 0.05-0.20 | | | Granulated edges. Recrystallized to an equigranular mosaic. Partially replaced by actinolite ± chlorite. |
| Clinopyroxene | — | 47 | | | | Completely replaced by amphibole. |
| Fe-Ti oxides | 1 | 3 | | | | Partially altered to sphene. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 27 | Hbd, plag | Replacing amphibole and plag, and in fracture. |
| Hornblende | 30 | Cpx | Altered to actinolite ± chlorite. |
| Chlorite? | Tr? | Plag, hbd | |
| Sphene | 2 | Oxides | |

**COMMENTS:** Thin section is perpendicular to foliation.
This rock was probably first metamorphosed to greenschist/amphibolite facies (gabbro metamorphosed into metagabbro). Shearing then produced the foliation. Both amphibole and plag are sheared and granulated. Shearing ends in cataclasis in the actinolite facies. Relict brown amphibole in the green hbd porphyroblasts suggests that original metamorphism was in the amphibolite facies; it is, however, possible that the brown amphibole is igneous.

## THIN SECTION DESCRIPTION

**118-733C-1D-1 (Piece 1, 0-3 cm)**

**ROCK NAME:** Metabasalt

**WHERE SAMPLED:**

**TEXTURE:** Porphyritic

**GRAIN SIZE:** Fine

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | — | 2 | 0.5-1.0 | | Euhedral | Completely replaced by amphibole + sphene. |
| Plagioclase | 10 | 10 | 0.5-3.0 | | Subhedral | Fractures filled with amphibole, replacing primary melt inclusions in some plag phenocrysts. |
| Clinopyroxene | <1 | 1 | 1.5 | | Anhedral | Cpx is partially replaced by actinolite. |
| GROUNDMASS | | | | | | |
| Plagioclase | 32 | 40 | | | Subhedral | Short, stubby crystal engulfed in mass of acicular amphibole. |
| Clinopyroxene | — | 45 | | | | Completely altered to actinolite. |
| Magnetite | 2 | 2 | | | Equant | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 55 | Cpx, ol, plag | Anhedral crystals replacing groundmass ol(?), cpx, and fractures in plag. Fills veins. |
| Sphene | Tr | Ol | |

**COMMENTS:** Percentages based on 1200 point counts.

## THIN SECTION DESCRIPTION

**118-733D-1D-1 (Piece 2, 10-12 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Very fine to medium (<0.01-2.00 mm)

**OBSERVER:** BLM/HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | 58(?) | 0.1–1.0 | | Anhedral | Porphyroclasts replacing primary plag. Deformation twins, shattered margins, granulated into smaller granoblasts. |
| Cpx | — | 40 | 1–4 | | Anhedral | Entirely replaced by green amphibole or chlorite. |
| Opx(?) | — | 2(?) | 1 | | Anhedral | Entirely replaced by green amphibole (and cummingtonite ?). |
| Oxide | 2 | 2 | | Magnetite | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 4 | Amphibole | Occurs along fractures and in patches. Pseudomorphs after cpx. |
| Actinolite | 10 | Plag, amphibole | Light green. Some patches are pleochroic brown to yellow; these are probably recrystallized brown hbd. Occurs along fractures in plag and amphibole, and along grain boundaries. These amphiboles are deformed, sheared. Large grains are deformed and infiltrating plag grains. Some fibrous crystals. |
| Hornblende | 15 | Cpx, opx(?) | Anhedral crystals, 0.1–2.0 mm in size. Deformed porphyroclasts. Some brown amphibole fragments. |
| Hornblende | 24 | Hbd | Recrystallized to <0.01–0.10 mm anhedral crystals. |
| Plagioclase | 30 | Plag | Irregular, anhedral crystals, <0.01–0.10 mm in size. Extensive recrystallization. |
| Magnetite | <1 | Amphibole | Enclosed in amphibole, as strings, idiomorphic grains or veinlets oriented in the foliation plane. |

**COMMENTS:** Thin section is oriented perpendicular to foliation.
Lensoid amphibole, plag with extensive granulation and recrystallization. High temperature metamorphism to amphibolite. Subsequent bending and fractures, cataclasis and recrystallization. Late replacement of amphibole by actinolite and chlorite. One or two very fine-grained, 2–3 mm wide mylonitic zones present. Intense shearing is composed of chlorite + fibrous actinolite and deformed actinolite grains.
Point count: plag (>0.1 cm) 18.1; plag (<0.1 cm) 21.8; amphibole (>0.1 cm) 19.2; amphibole (<0.1 cm) 35.8; opaque 0.6; chlorite 0.7; actinolite 3.6 (counted an arbitrary distance from fine amphibole).

## THIN SECTION DESCRIPTION

**118-733D-1D-1 (Piece 1, 2-5 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:**

**OBSERVER:** STA/MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 12.2 | 55 | 1–2 | | Ovoid | Porphyroclasts. Undulatory extinction. |
| Clinopyroxene | 14.9 | 39 | 0.8–1.0 | | Anhedral | Relict cleavage, replaced by cpx and hbd. |
| Hornblende | 2.0 | 2 | 0.5 | | Anhedral | Red-brown. Rims altered to amphibole. Inclusions in cpx. |
| Orthopyroxene | 0.5 | 4 | ≈1.0 | | Elongate | Elongate porphyroclasts. Partially replaced by amphibole |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.0 | Plag, opx | Associated with actinolite? |
| Actinolite | 18.0 | Px | Pale green. Undeformed. Preferentially replaces unrecrystallized px. |
| Hornblende | 1.0 | Hbd(?) | Brown-green. In recrystallized mosaic. |
| Plagioclase | 42.3 | Plag | 0.02–0.10 mm recrystallized crystals. |
| Clinopyroxene | 6.9 | Cpx | 0.01–0.02 mm in size. |
| Rutile | Tr | Ilmenite | Deep red. |
| Magnetite | 1.2 | Cpx(?) | |

**COMMENTS:** Abundant hbd in px recrystallization zones.
Late veins, filled with green amphibole.
Red inclusions in px may be rutile.

## THIN SECTION DESCRIPTION

**118-733D-1D-1 (Piece 2A, 12-14 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Gneissic layering

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 25 | 50 | 2-5 | | Anhedral | Relict porphyroclasts. Strained. Recrystallized. |
| Clinopyroxene | 18 | 21 | | | Anhedral | Mechanical twinning. Slip zones. Recrystallized. |
| Spinel | 2 | 2 | | Ilmenite | | |
| Orthopyroxene | 12 | 21 | | | Elongate | Elongate, spindle crystals. Also recrystallized in mortar. |
| Hornblende | 3(?) | 6 | | | Anhedral | Clear, red-brown in cpx. Optically indistinguishable from secondary hbd. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Px(?) | Late celadonite mixed with hematite. |
| Actinolite | 3 | Hbd | Late, replacing hbd. |
| Hornblende | (?) | Cpx, veins | Green-brown in cross cutting veins. Replacing cpx. |
| Plagioclase | 25 | Plag | Mosaic of recrystallized neoblasts. |
| Magnetite | 1 | Opx, ilmenite | In veins in opx. |
| Talc(?) | 2 | Opx | Possibly cummingtonite. Veins in opx. |
| Cummingtonite | 5 | Opx | Replacing opx. Undeformed. |
| Clinopyroxene | 3 | Cpx | Recrystallized in mortar. Neoblasts. |
| Opx | Tr | Opx | Recrystallized neoblasts. |

**COMMENTS:** Late fractures through opx are filled with magnetite and fine-grained mineral which is possibly talc or cummingtonite.
Plag and cpx recrystallized neoblasts, elongate opx crystals, and recrystallized opx neoblasts are a product of high temperature plastic deformation.
Metamorphic fluids formed hbd + cummingtonite (or talc) + actinolite.

## THIN SECTION DESCRIPTION

**118-733D-1D-1 (Piece 2B, 15-23 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:** Medium-grained portion of thin section (see following description)

**TEXTURE:** Granoporphyroclastic

**GRAIN SIZE:** Medium (0.5-3.0 mm)

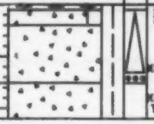
**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 50 | 0.3-2.0 | An 50 | Euhedral, lensoid | Included in cpx and opx. Deformed twin planes. |
| Clinopyroxene | 25 | 30 | 0.2-1.8 | Augite | Subhedral, irregular | Contain opx exsolution, brown hbd patches. Strained. |
| Orthopyroxene | 17 | 20 | 0.5-2.0 | Hypersthene | Irregular | Deformed, strained. Contain cpx exsolution. Slight replacement by actinolite and cummingtonite. |
| Amphibole | Tr | Tr | 0.03-0.05 | | Irregular | Inclusions in cpx. Associated with small ilmenite grains. |
| Ilmenite | Tr | Tr | 0.04-0.08 | | Irregular | Included in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 3 | Opx, cpx | Pale green, very small needles at opx and cpx margins. Also in very thin veinlets of very late stage metamorphism. Both are interrelated. May grade into hbd in veinlets or at actinolite margins. Possibly forming pseudomorphs after cpx. |
| Plagioclase | 40 | Plag | Neoblasts, 0.01-0.30 mm in size. Polygonal crystals with abundant triple junctions. Surrounding plag. |
| Clinopyroxene | 5 | Cpx | Polygonal neoblasts, 0.04-0.20 mm in size. Around or near cpx. |
| Cummingtonite | Tr | Opx | Small needles at outer rims of opx. |

**COMMENTS:** This description is valid for the medium-grained, more mafic part of the large thin section (see following description).
Starting assemblage: plag + cpx + opx
Indication that cumulus plag precedes both px crystallization.
High temperature deformation: porphyroclasts and neoblasts develop. The foliation is more regular and as neoblasts are not very abundant, it is suggested that the grain size was smaller than the other part of the thin section.
Low temperature alteration of the same type described for the coarse grained portion of the rock.

SITE 734 HOLE B CORE 1R CORED INTERVAL 3681.5-3691.0 mbsl; 0.0-9.5 mbsf

| TIME-ROCK UNIT | BIOSTRAT. ZONE/ FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYS. PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HOLOCENE | | NN 21 | | | | | | 1<br>CC | 0.5 |  | | | XRF<br>XRD<br>TS |

LITHOLOGIC DESCRIPTION

FORAMINIFERAL OOZE, VOLCANIC GRAVEL, and VOLCANIC SAND

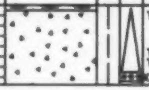
Major lithologies:
- a. FORAMINIFERAL OOZE, light brownish gray (2.5Y 6/2) to light gray (2.5Y 7/2), very fine sand to fine sand, in Section 1, 0-4 cm. Sharp basal contact.
- b. One graded bed, fining upward from VOLCANIC GRAVEL (pebbles as large as 3.5 cm) to fine-grained VOLCANIC SAND, both serpentinized peridotite, in Section 1, 4-76 cm.
- c. Volcanic and metamorphic gravel of serpentinized peridotite, dark grayish brown and black (2.5Y 4/2 to 2.5Y 2/2), in CC.

Minor lithologies:
- a. Alteration mineral form 10% of Section 1, 4-76 cm: carbonate minerals and zeolites, and altered gabbro(?), with some foraminiferal ooze from 4-24 cm. Serpentinite grains are angular.
- b. Greenstone with ophicalcite veins, in CC.

SMEAR SLIDE SUMMARY (%):

| | 1, 1<br>D | 1, 2<br>D | 1, 15<br>D |
|---|---|---|---|
| TEXTURE: | | | |
| Sand | 90 | 95 | 100 |
| Silt | 10 | 5 | — |
| COMPOSTION: | | | |
| Acc. min. | 10 | 5 | 5 |
| Feldspar | 10 | 5 | — |
| Foraminifers | 80 | 80 | 5 |
| Rock frag. | — | 10 | 90 |

SITE 734 HOLE D CORE 1R CORED INTERVAL 3720.0-3739.5 mbsl; 0.0-19.5 mbsf

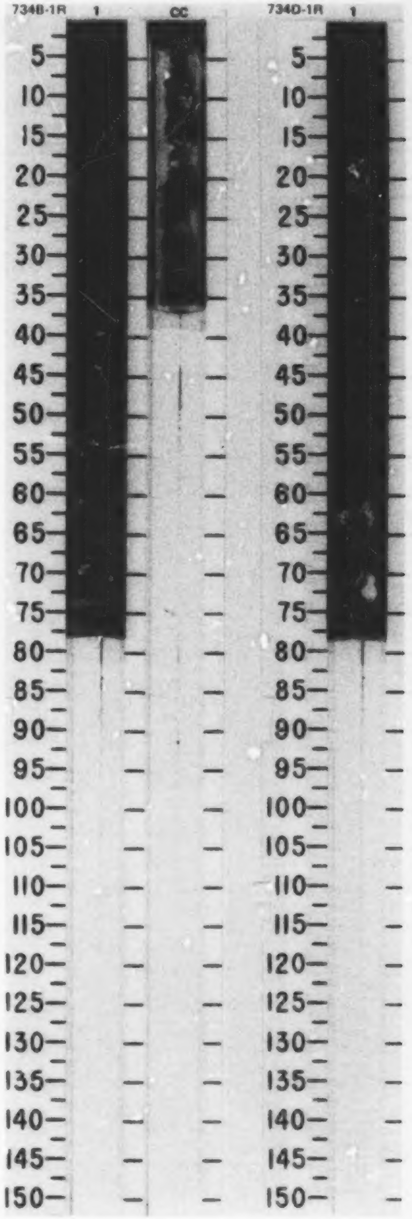
| TIME-ROCK UNIT | BIOSTRAT. ZONE/ FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYS. PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HOLOCENE | | NN 21 | | | | | | 1 | 0.5 |  | | | TS<br>TS<br>TS<br>XRF |

LITHOLOGIC DESCRIPTION

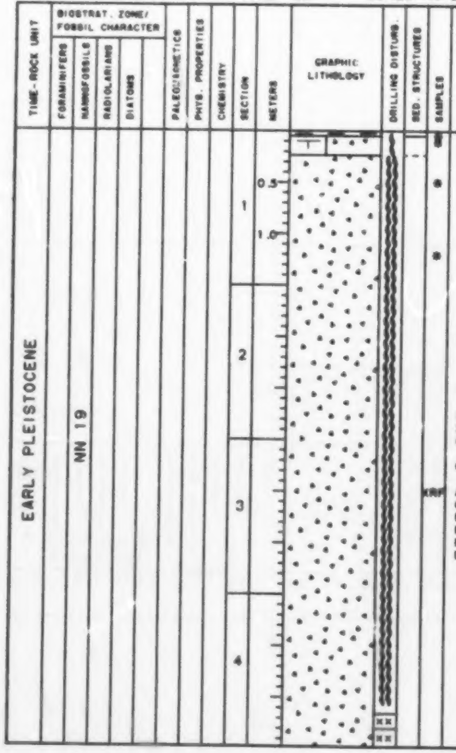
VOLCANIC GRAVEL and VOLCANIC SAND

Major lithology: One graded bed, fining upward from VOLCANIC GRAVEL (with pebbles as large as 4.5 cm) to medium-grained VOLCANIC SAND. Amphibolite mylonite, very dark gray to black (2.5Y 3/0 to 2.5Y 2/0), forming 80% of core. All volcanic grains are angular.

Minor lithologies:
- a. Serpentinized peridotite, very dark grayish brown (2.5Y 8/0), 5% of core.
- b. Calcite, white (2.5Y 8/0), 15% of core.
- c. Foraminiferal ooze, light brownish grey (2.5Y 6/2), >80% of sediment in upper 5 cm.
- d. Large clast of foliated serpentinized peridotite, containing porphyroblast of orthopyroxene ~0.5-1.0 cm in size, and a trace of clinopyroxene. Olivine is totally serpentinized. Veins are filled by an unidentified white mineral.



SITE 734 HOLE G CORE 3D CORED INTERVAL 3451.0-3459.5 mbsl; 22.5-31.0 mbsf


TIME-ROCK UNIT
BIOSTRAT. ZONE/ FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
PALEOMAGNETICS
PHYS. PROPERTIES
CHEMISTRY
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURB.
SED. STRUCTURES
SAMPLES
EARLY PLEISTOCENE
NN 19
1
2
3
4
0.5
1.0
XRF

LITHOLOGIC DESCRIPTION

VOLCANIC BRECCIA

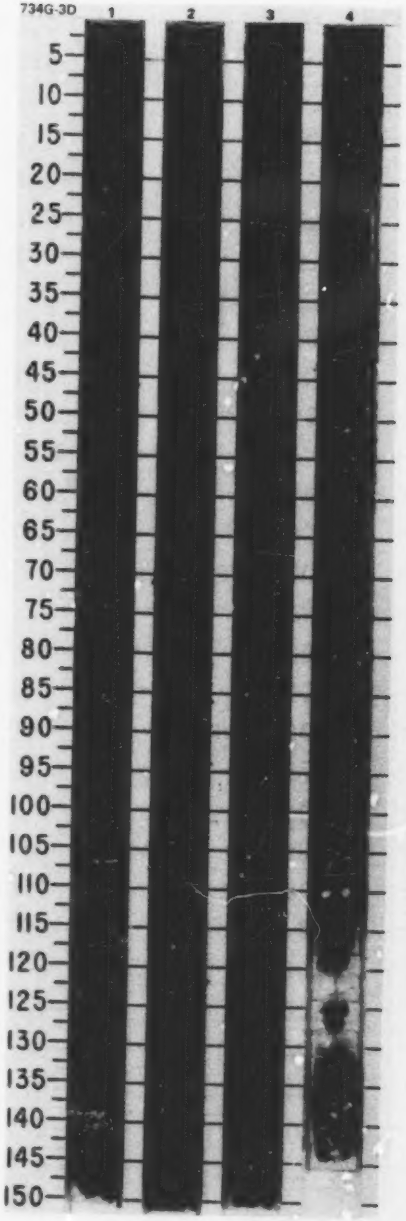
Entire core is badly deformed. Core was a slurry upon extrusion.

Major lithology: VOLCANIC BRECCIA, very dark grayish brown (2.5Y 3/2), with olive brown (2.5Y 4/4), white (2.5Y 8/2), and yellowish red (5YR 5/8) sand grains. Graded, fining upward from pebble conglomerate at base of core to sandy silty clay at top. Poorly sorted throughout. Stratification only in top 25 cm.

Minor lithologies:
a. Calcareous ooze, light olive brown (2.5Y 5/4), homogeneous, stiff, in Section 1, 0-3 cm.
b. Foraminiferal ooze, olive brown (2.5Y 4/4), intermixed with underlying breccia, in Section 1, 3-20 cm.

SMEAR SLIDE SUMMARY (%):

| | 1, 2<br>D | 1, 10<br>D | 1, 50<br>D | 1, 120<br>D |
|---|---|---|---|---|
| TEXTURE: | | | | |
| Sand | 20 | 80 | 80 | 90 |
| Silt | 40 | 15 | 5 | 5 |
| Clay | 40 | 5 | 5 | 5 |
| COMPOSITION: | | | | |
| Acc. min. | 10 | 33 | 30 | 22 |
| Carbonate | 80 | 5 | 5 | 10 |
| Feldspar | — | 20 | 5 | — |
| Foraminifers | 5 | 30 | 10 | 8 |
| Nannofossils | 5 | 2 | — | — |
| Rock frag. | — | 10 | 50 | 60 |


734G-3D
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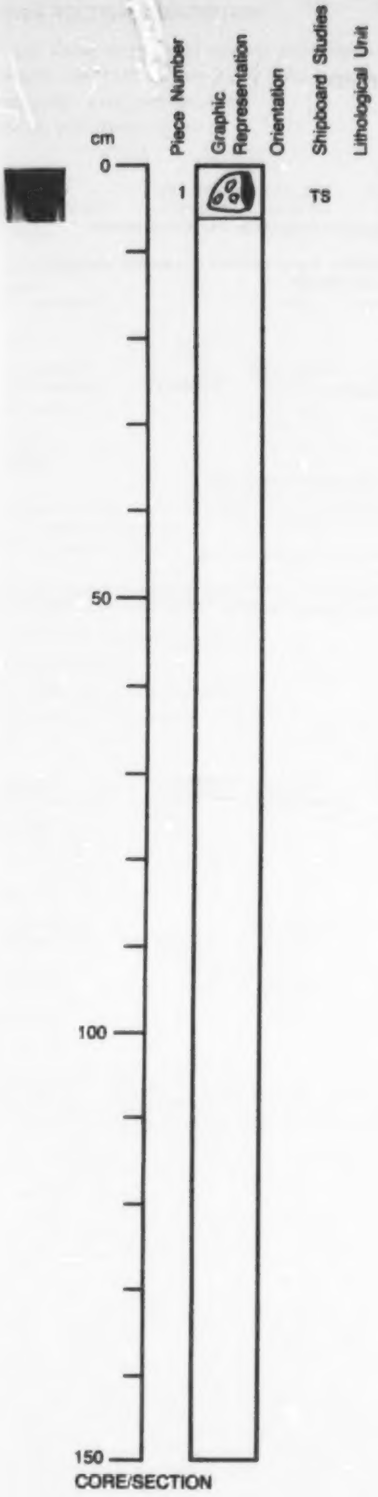


118-734A-1D-1

## UNIT 1: SERPENTINIZED LHERZOLITE

**Piece 1:**

**COLOR:** Buff, mottled gray, dark greenish black at one edge.
**LAYERING:** None.
**DEFORMATION:** Very slight foliation in brownish matrix, parallels dark edge.
**PRIMARY MINERALOGY:**

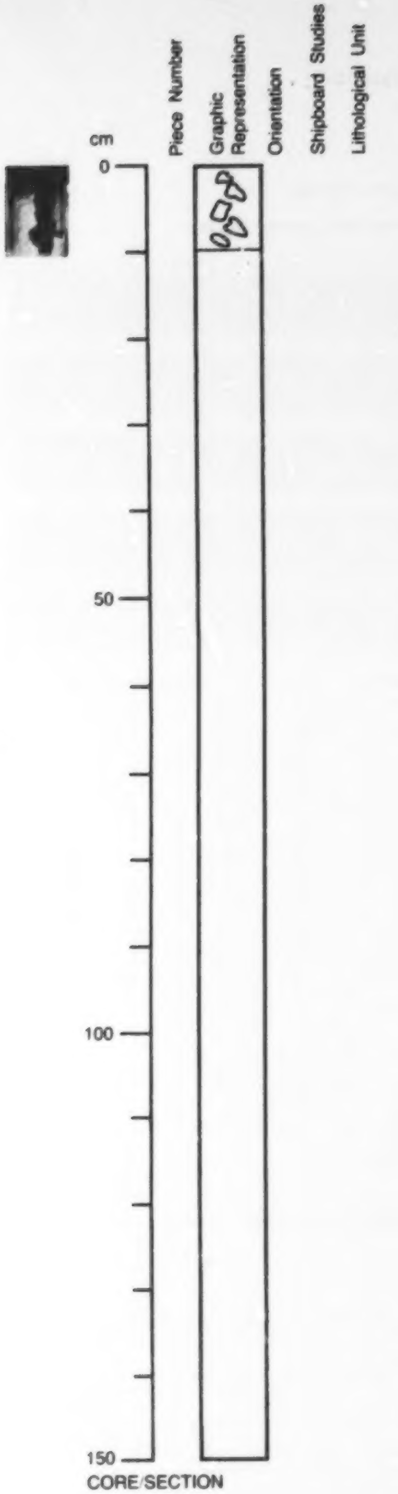
Olivine—Mode: 75%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Serpentinized.

Orthopyroxene—Mode: 20%.
Crystal size: Up to 0.5 cm.
Crystal shape: Porphyroblasts.
Preferred orientation: Not determined.
Percent replacement: Largely fresh.

Clinopyroxene—Mode: 5%.
Crystal size: Individual large crystals.
Crystal shape: Most disseminated in sheared serpentinite.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Serpentine replaces most olivine. Orthopyroxene rimmed by talc (yellowish). Archive portion has thin patina of manganese oxyhydroxides, working portion does not. Rock is apparently a pebble in the thin rubble zone above coherent rock. It was partly exposed to sea water.
Percent vein material: Not determined.
Vein material: Not determined.



118-734F-1D-1

## UNIT 1: SERPENTINIZED PERIDOTITE

### Piece 1

### Piece 1: Serpentinized Peridotite

**COLOR:** Pieces have dark brownish-black external colors stained by orange iron-oxides(?).
**LAYERING:** None.
**DEFORMATION:** Foliation defined by some elongation of orthopyroxene and parallel orientation of serpentinite veins in two chips, other more massive.
**PRIMARY MINERALOGY:**
Olivine—Mode: 80-100%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Replaced by serpentine.

Orthopyroxene—Mode: Not determined.
Crystal size: 3-4 mm.
Crystal shape: Porphyroblasts.
Preferred orientation: Crystals are elongate due to deformation.
Percent replacement: 80% replaced by serpentine and iron-oxides.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Serpentine and iron-oxides, form 75%-100% of the rock.
Percent vein material: Not determined.
Vein material: Serpentine veinlets generally have a consistent orientation throughout. One chip has a transverse vein, 5 mm wide which crosscuts the serpentine veinlets throughout the rest of the sample.

## THIN SECTION DESCRIPTION

**118-734A-1D-1 (Piece 1, 0-5 cm)**

**ROCK NAME:** Serpentinized peridotite, spinel lherzolite

**WHERE SAMPLED:** Perpendicular to lineation produced by serpentinization. Rubble.

**TEXTURE:** Mesh, porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | ≈70(?) | 0.1–0.2 | | | Partially replaced. Mostly occurs as tiny crystals or granulated masses interspersed with serpentine. Mesh texture. |
| Clinopyroxene | 5 | ≈10 | 1–2 | | Anhedral | Occurs as clusters of small, equant crystals near opx. |
| Spinel | Tr | Tr | | | Anhedral | |
| Orthopyroxene | 3 | ≈20 | 0.1–5.0 | | | Almost completely replaced by serpentine. Recrystallized crystals measure 0.1–0.2 mm; other crystals measure 3–5 mm. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Serpentine | 71 | Ol, opx, cpx | |
| Magnetite | 11 | Ol, opx | |
| Bastite. | Tr | Opx | 0.1–0.2 mm recrystallized crystals. Halos around porphyroclasts. |

**COMMENTS:** Thin section is probably perpendicular to spinel foliation and to extensional fractures produced by serpentinization. Recrystallized opx crystals are <0.2 mm in size. Unrecrystallized crystals of opx and cpx show exsolution lamellae. Opx crystals measure 3–5 mm; cpx crystals measure 1–2 mm.

## THIN SECTION DESCRIPTION

**118-734B-1R-CC (Piece 3, 8-10 cm)**

**ROCK NAME:** Serpentinized peridotite

**WHERE SAMPLED:**

**TEXTURE:** Mesh, porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | | | | Anhedral | |
| Clinopyroxene | 5 | | | | Anhedral | |
| Spinel | 1.2 | 2 | 1–4 | Chromite | Anhedral | Rimmed and replaced by magnetite or ferrous chromite. Cr spinel is golden brown. |
| Orthopyroxene | 2.7 | | 3–5 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 7.5 | Veins | Calcite in ≈1 mm wide veins which cross cut the extensional fractures by serpentinization. |
| Serpentine | 73.8 | Ol, opx, veins | Forms mesh texture. Bastite replaces opx. Vein is ≈5 mm wide. |
| Magnetite | 1.8 | Spinel | Occurs as small crystals throughout serpentine and as slightly larger equant crystals lining the sides of calcite veins. |

**COMMENTS:** Clinopyroxene occurs as clusters of small crystals near opx and cpx porphyroclasts. Recrystallized px measures ≈0.2–0.3 mm. Unrecrystallized opx shows exsolution of cpx, and measures from 3–5 mm. Unrecrystallized cpx is 1–4 mm in size. Original mineral proportions unknown due to extensive alteration and deformation. Percentages based on 500+ point counts.

## THIN SECTION DESCRIPTION

**118-734B-1R-CC (Piece 2, 5-7 cm)**

**ROCK NAME:** Anorthosite metagabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse to very coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 85 | 0.5-0.8 |  | Subhedral | Define an original lamination. |
| Clinopyroxene | — | 15(?) |  |  |  | Altered to clays, amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 20 | Plag | Brown aggregates. Also filling fractures. |
| Actinolite | 25 | Plag | Fibrous aggregates replacing plag and in fractures cutting across lamination (probably prehnite?). |
| Amphibole | 15 | Cpx(?) | Anhedral, clear, nonpleochroic, optically negative crystals. Z ∧ c = 25°. Good amphibole cleavage. Interstitial to plag; looks like replacing interstitial subpoikilitic cpx. |
| Opaques | <1 | Plag | Opaques + actinolite replacing plag. |

**COMMENTS:** Looks like a plag orthocumulate with an original lamination. Interstitial cpx is completely replaced by high temperature amphibole and later low temperature alteration minerals. Dense network of fractures perpendicular to lamination filled with amphibole + clay. Some minor bending, breakage, and recrystallization of plag. Amphibole is optically negative, probably a Mg actinolite. Calcisilicate (2Vx = 25°) may be wollastonite.
Thin section cut from a piece of volcanic rock (in the core catcher).

## THIN SECTION DESCRIPTION

**118-734D-1R-1 (Piece 1, 18-24 cm)**

**ROCK NAME:** Serpentinized harzburgite

**WHERE SAMPLED:**

**TEXTURE:** Mesh

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4.9 | (?) | 0.1-0.2 |  | Anhedral | Occurs as small clear crystals interwoven in serpentine mesh texture. Generally these areas are oxidized, darker than surrounding serpentine. |
| Clinopyroxene | 1.2 | (?) |  |  | Anhedral |  |
| Spinel | 0.5 | ≈ 1 | 0.05-0.30 |  | Holly-leaf vermicular, anhedral |  |
| Orthopyroxene | 3.5 | ≈ 10 | 10-15 |  | Anhedral | Elongated. Some crystals show en echelon fractures along which slip has occurred. Bastite. Average crystal width = 3-4 mm. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 1.5 | Veins | Calcite. |
| Serpentine | 77 | Ol. opx. veins | In veins perpendicular to lineation defined by elongate opx. |
| Magnetite | 11.4 | Ol. opx |  |

**COMMENTS:** Percentages based on 529 point counts.
One interesting symplectic intergrowth of spinel + cpx in opx.
Foliation/lineation defined by elongation of opx porphyroclasts and strings of holly-leaf shaped spinels.
Thin section parallel or subparallel to foliation.

## THIN SECTION DESCRIPTION

**118-734D-1R-1 (Piece 1, 59-61 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10(?) | 70 | | | | Most crystals are altered. A few remnant crystals of calcic plag. |
| Clinopyroxene | 20 | 30 | | | | Two large crystals: one is bent and shows granulation and recrystallization. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 30 | Plag | Dark aggregates after plag. Probably nontronite. |
| Carbonate | 2 | Veins | In veins perpendicular to direction of cpx lenses. |
| Zeolites | 10 | Plag | Natrolite (composition determined by XRD). |
| Albite | 10 | Plag, veins | Veins perpendicular to cpx lenses. |
| Sphene | 5 | Cpx?? | Orange-yellow crystals around cpx. Associated with opaques. |
| Amphibole | 10 | Cpx | Clear small amphibole crystals around cpx margins (clear cpx cores). Then cloudy zone of mixed cpx + amphibole. Then small amphibole crystals. Also in small patches in altered cpx. |
| Opaques | 3 | Cpx | Around edges of cpx, with sphene. |

**COMMENTS:** High temperature alteration of gabbro was followed by low temperature alteration; plag was almost completely replaced by clays and albite, and cpx was partially replaced by amphibole. Final assemblage is cut by dense fracture network, largely perpendicular to cpx lenses (a few parallel to lenses). Some fractures are filled with albite, clay, calcite.

## THIN SECTION DESCRIPTION

**118-734D-1R-1 (Piece 1, 67-68 cm)**

**ROCK NAME:** Mylonitic amphibolite

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 30(?) | | | | Replaced by both porphyroblasts and neoblasts of plag (<0.01 mm). |
| Clinopyroxene | — | 70(?) | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Veins | |
| Amphibole | 70 | Cpx(?), amphibole(?) | Anhedral, colorless crystals. Occur as large porphyroclasts (2-10 mm) and as small neoblasts (<0.1 mm). |
| Plagioclase | 29 | Plag | Occurs as both porphyroclasts (2-10 mm) and as small neoblasts <0.1 mm. Undulatory extinction. |

**COMMENTS:** Tendency for mineralogic segregation in amphibole and plag-rich layers.
Thin vein of chlorite crossing one corner of slide.
Amphibole augen with mechanical twins(?). Some recrystallization along en echelon fractures in these crystals. These fractures lengthen the augen in the plane of the foliation.

## THIN SECTION DESCRIPTION

**118-734D-1R-1 (Piece 1, 74-77 cm)**

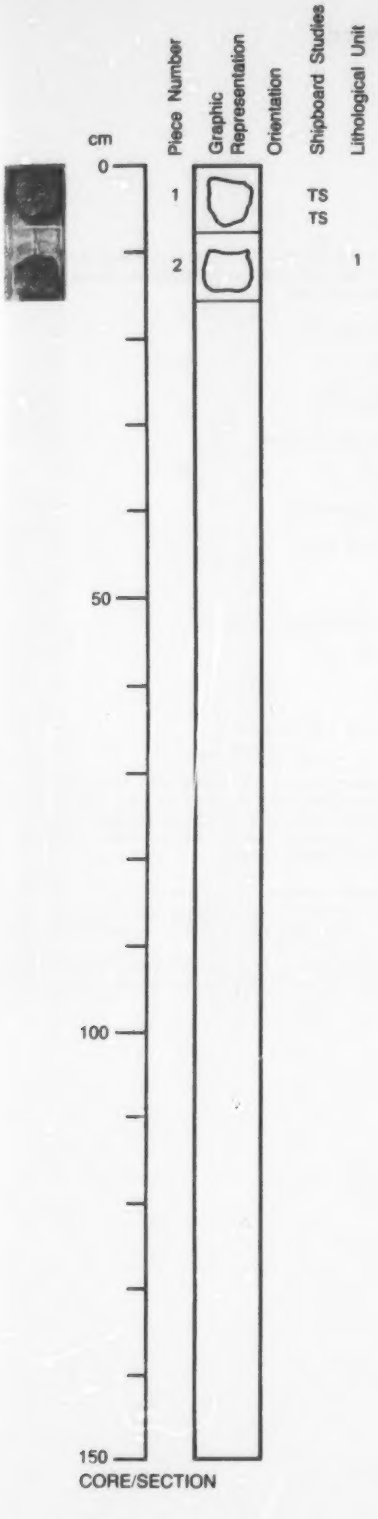
**ROCK NAME:** Foliated metabasalt (amphibolite?)
**WHERE SAMPLED:** Rubble
**TEXTURE:** Granoblastic
**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 2 | 3-5(?) | 0.1-0.5 | | Euhedral | Magmatic twins. Clear preferred orientation of crystals with these twins. Maximum elongation parallel to the foliation. Locally the phenocrysts also show mechanical twins. |
| Opaques | Tr | Tr | | | | |
| Groundmass | — | 95 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Prehenite(?) | 18 | Plag, veins | Replaces plag close to the cross cutting veins. Cross cutting veins of prehnite or laumontite(?). |
| Opaques | 10 | | Small grains ($<30\mu$m) in the groundmass and as larger grains (0.1 mm) elongated in the foliation. Possibly primary. |
| Plagioclase | 30 | Plag, groundmass | Recrystallized grains from the plag phenocryst ($\approx$ 40 $\mu$m) and from the basaltic groundmass ($\approx$ 20 $\mu$m). |
| Amphibole | 40 | | Pale brown to pale green, polygonal grains 20-50 $\mu$m in the groundmass. Some amphibole grains larger (0.2 mm). Also in monomineralic layers, 0.5-2.0 mm wide. Probably replacing cpx microphenocrysts. |

**COMMENTS:** 1) Plag phenocrysts with magmatic twins are relicts of the primary basalt.
2) Deformation occurred in the conditions of crystallization/recrystallization of plag + pale brown-green hbd. The origin of the amphibole layers is not clear (igneous or metamorphic?). The layers seem locally folded with the foliation defining the axial plane.
3) The thin section is perpendicular to the foliation.



**118-735A-1D-1**

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1 and 2**

**Foliated Metagabbro**

**Pieces 1 and 2**

**COLOR:** Variegated dark grayish green to grayish white.
**LAYERING:** None.
**DEFORMATION:** Samples are crudely foliated, but core is unoriented. Defined by elongation of plagioclase and clinopyroxene.
**PRIMARY MINERALOGY:**

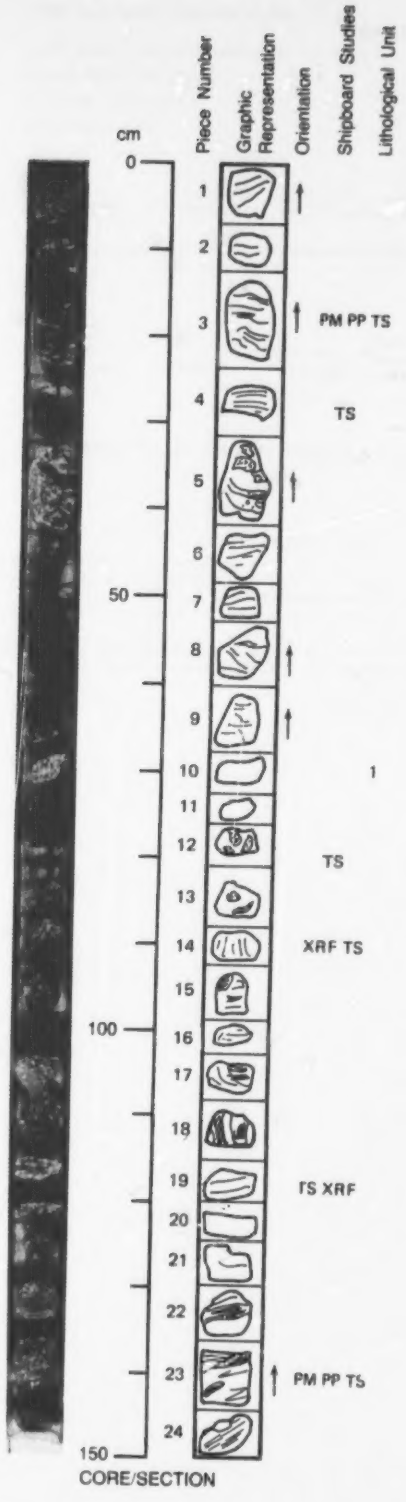
Plagioclase—Mode: 30%.
Crystal size: Up to 1 cm.
Crystal shape: Elongate in plane of foliation.
Preferred orientation: In plane of foliation.
Percent replacement: 75% by albite and actinolite.

Clinopyroxene—Mode: 30%.
Crystal size: Up to 4 mm.
Crystal shape: Most equant and anhedral, some slightly elongate in plane of foliation.
Preferred orientation: In plane of foliation.
Percent replacement: 20%.

Olivine—Mode: 5%.
Crystal size: Size difficult to estimate because of total alteration.
Crystal shape: Anhedral.
Preferred orientation: <2 mm.
Percent replacement: 100% with orange-brown mineral (Fe-oxide?).

**SECONDARY MINERALOGY:**

Total percent: 20%.
Texture: Amphibole replaces clinopyroxene and forms elongate masses that along with plagioclase define the foliation. Olivine altered to iron-oxides, and plagioclase recrystallized and replaced by albite and actinolite.
Percent vein material: No veins.
Vein material: none.



### 118-735B-1D-1

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-24**

**Foliated Metagabbro**

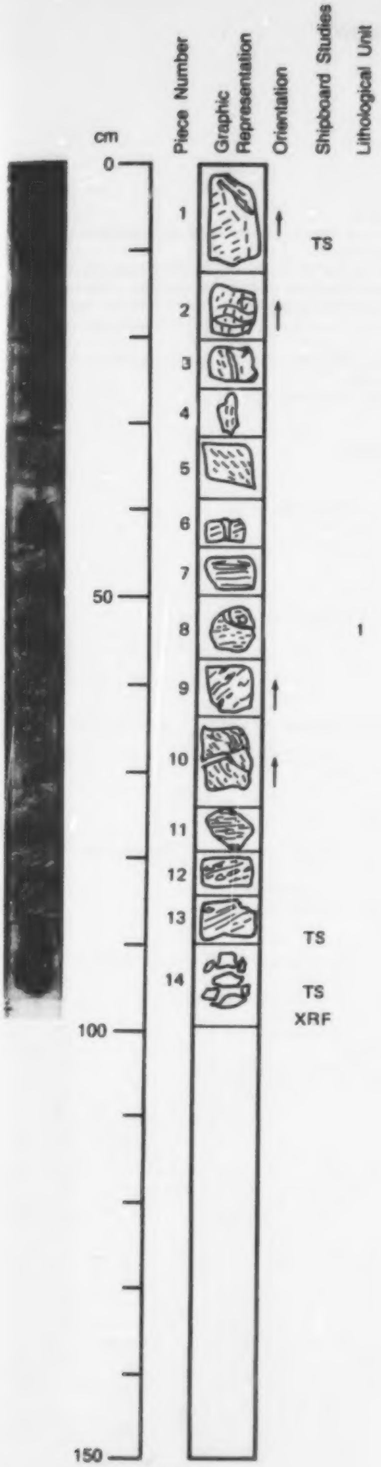
**Pieces 1-24**

**COLOR:** Variegated greenish-dark gray to white.
**LAYERING:** No primary layering apparent.
**DEFORMATION:** Mylonitic zones in Piece 4 (25-30 cm) and Piece 22 (130-135 cm). Foliation defined by granulated pyroxene lenses and by deformed and recrystallized plagioclase; lenses may defin a lineation in foliation, but unclear. Dipping 14°-45°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50% (originally), 5% (now).
Crystal size: <0.5 mm.
Crystal shape: Anhedral porphyroclasts.
Preferred orientation: In foliation.
Percent replacement: 90%, recrystallized—albite.

Clinopyroxene—Mode: 37% (originally), 10%-20% (now).
Crystal size: Up to 1 cm.
Crystal shape: Anhedral porphyroclasts.
Preferred orientation: In foliation.
Percent replacement: 60%, neoblasts, amphibole.

Orthopyroxene—Mode: 10% (originally), 5% (now).
Crystal size: Up to 0.5 mm.
Crystal shape: Anhedral porphyroclasts.
Preferred orientation: In foliation.
Percent replacement: 90%, oxidized red clay minerals, amphibole.

Olivine—Mode: 3% (originally), 0% (now).
Crystal size: 1-2 mm.
Crystal shape: Anhedral porphyroclasts.
Preferred orientation: In foliation.
Percent replacement: Soft red clay minerals, 100% replaced.
**SECONDARY MINERALOGY:**
Total percent: 40%-95%.
Texture: Includes plagioclase and pyroxene neoblasts. First replacement—orthopyroxene or olivine replaced by red clayey pseudomorphs with thin S-shapes in foliation. There are white/green zones cutting the foliation at various angles. There appear to be alteration fronts where a green amphibole has pseudomorphed the pyroxene porphyroclasts and albitic plagioclase has replaced the plagioclase neoblasts (e.g., Pieces 2 and 3).
Percent vein material: 2%.
Vein material: Most as amphibole-filled veins cutting fractured pyroxene grains.
**COMMENTS:** Deformation intensity varies greatly. Pieces 10-12 are coarse-grained and show the least well-developed foliation. The foliation is more marked and the layers finer grained as the rocks are more deformed—section includes mylonitic zones as noted.
The amphibolitized zones vary along the core; some clearly post-date deformation, while in other areas the amphibole looks to be deformed as well and may be syndeformational.



**118-735B-1D-2**

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-14**

**Foliated Metagabbro**

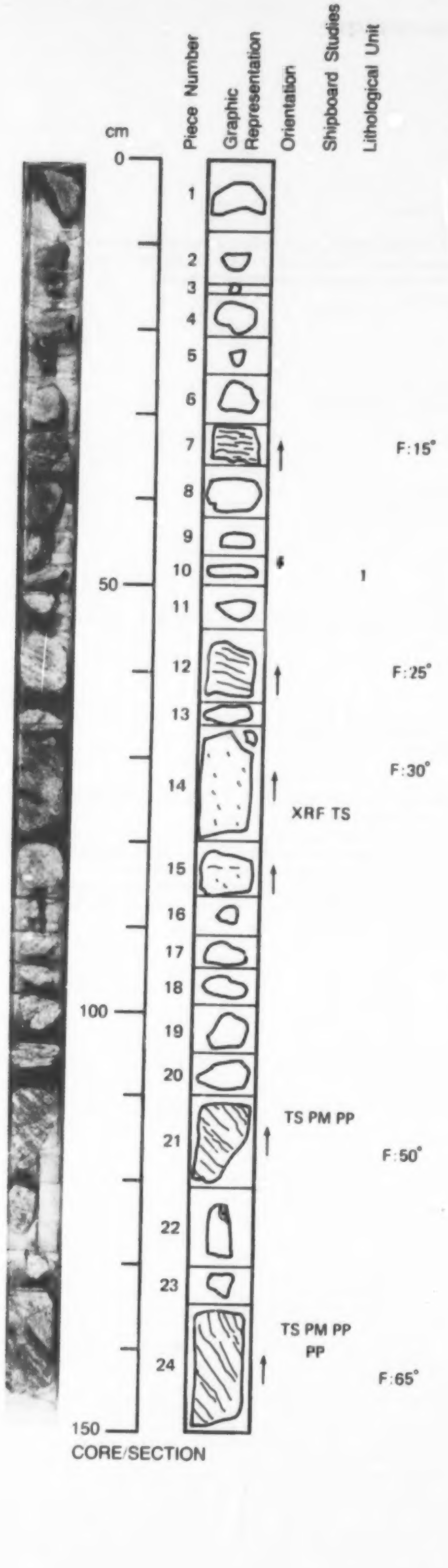
**Pieces 1-14**

**COLOR:** Variegated greenish-dark gray to white.
**LAYERING:** No primary layering apparent.
**DEFORMATION:** Well-developed gneissic foliation dipping close to 30° in all four oriented samples.
Ranges from coarse-grained augen gneiss (Pieces 9-13) at bottom of section to medium-grained gneiss containing 1-4 mm augen of oxidized pyroxene (Pieces 1-8).
Pieces 7, 11, and 13: Mylonitic zones.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: none determined.
Percent replacement: 50-90% to sodic plagioclase.

Clinopyroxene—Mode: 33%-35%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: none observed.
Percent replacement: 50-90% by amphibole.

Hypersthene—Mode: 3%-5%.
Crystal size: 0.5-2 mm.
Crystal shape: Anhedral.
Preferred orientation: none observed.
Percent replacement: 60%. Extensively oxidized to a rust-red or yellow clay mineral and carbonate.

Ilmenite—Mode: 2%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Occurs as bands and schlieren along foliation.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 10%-25%.
Texture: Extensive zones of albitization occuring concentrically about crosscutting amphibole veins. Sharp contacts between albitized zones and less altered rock.
Piece 1: Spectacular plumose texture. Adjacent to amphibole vein (2-5 mm thick), primary pyroxene is altered to amphibole and plagioclase to milky albite in a wedge-shaped zone up to 4 cm wide. Many of the pyroxene are rimmed or pseudomorphed by amphibole.
Many of the amphibole veins crosscut and crisscross the foliated gneiss, while others appear to have been deformed with the primary minerals and are stretched out along the plane of foliation.
Percent vein material: 1%
Vein material: Amphibole.



## 118-735B-2D-1

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-24**

**Foliated Metagabbro**

**Pieces 1-24**

**COLOR:** Gray with brownish oxidized orthopyroxene.

**LAYERING:** Some phase layering with mafic-rich (not Pieces 7, 8, and 20-22) and mafic-poor portions. Possible modal layering. Layer contacts unclear.

**DEFORMATION:** Foliation is variable, 15° at the top and 65° at the bottom, partly mylonitic. Gneissic layering of plagioclase-rich and pyroxene-rich layers. Lineation is clear and is almost parallel to dips of foliation. Grain size: Porphyroclastic clinopyroxene ~1-7 mm across; neoblastic clinopyroxene <1 mm; orthopyroxene or olivine pseudomorphs ~1 mm; and plagioclase (neoblast) <1 mm.

Porphyroclast/neoblast ratio varies widely (50%-95%) showing various degrees of deformation.

Pieces 14 and 15: Have weak, vague foliation.

Pieces 8 and 10: Are mylonitic with ~95% neoblasts.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: ~50%.
Crystal size: Unknown, now <1mm (neoblast).
Crystal shape: Unknown, now anhedral.
Preferred orientation: Not evident.
Percent replacement: Replaced with sodic plagioclase, ~70%.

Clinopyroxene—Mode: ~40%.
Crystal size: 1.8 cm.
Crystal shape: Anhedral.
Preferred orientation: Not evident.
Percent replacement: Variable (50%-95%). Replaced with amphibole.

Orthopyroxene—Mode: ~25%.
Crystal size: <1mm.
Crystal shape: Anhedral.
Preferred orientation: Not evident.
Percent replacement: Variable (50%-100%). Replaced by hematite + smectite + calcite aggregate.

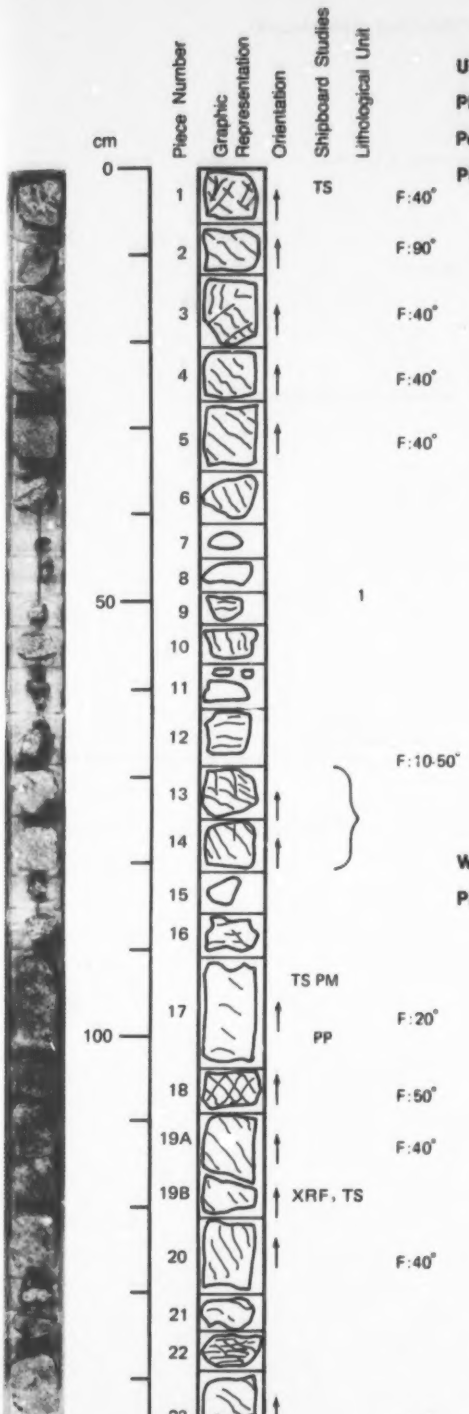
Olivine—Mode: >1%.
Crystal size: <1mm.
Crystal shape: Unknown (now anhedral due to deformation)
Preferred orientation: Not evident.
Percent replacement: 100%. Replaced by hematite + smectite + calcite aggregate.

**SECONDARY MINERALOGY:**

Total percent: 50%-95% neoblast, and up to 20% amphibole.
Texture: Secondary phases appear as neoblast in mylonite matrix.
Plagioclase recrystallized into neoblast.
Percent vein material: Not determined.
Vein material: Amphibole veins ~0.7 mm wide, inclined at ~30°—perpendicular to the foliation and the lineation.

**COMMENTS:** Pieces are classified into four types by textural characteristics:

(1) Mylonitic gabbro (Pieces 2, 5, 8, 10, and part of 24).
(2) Porphyroclastic gabbro (Pieces 3, 4, 6, 7, 9, 11, and part of 24).
(3) Well-foliated gabbro (Pieces 1, and 13-17).
(4) Gneissic to augen gneissic metagabbro (Pieces 12, and 18-23).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F:40°
F:40°
F:40°
F:10-50°
F:20°
F:50°
F:40°
F:40°
F:40°

### 118-735B-2D-2

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-23

### Porphyroclastic Metagabbro

### Pieces 1, 6, 10, 12, and 16

**COLOR:** Greenish gray
**LAYERING:** Faint magmatic layering, normal to foliation.
**DEFORMATION:** Foliation defined by flattening of plagioclase and pyroxene to poorly defined gneissic bands.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-60%.
Crystal size: 1-20 mm.
Crystal shape: Elongated and recrystallized in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: 40%. Replaced by secondary plagioclase.

Orthopyroxene—Mode: 5%-25%.
Crystal size: 1-20 mm.
Crystal shape: Elongated and recrystallized in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: 100%. Iron oxides.

Clinopyroxene—Mode: 15% up to 38%.
Crystal size: 1-20 mm.
Crystal shape: Elongated and recrystallized in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: 25%. Green amphibole.

Ilmenite—Mode: <1%.
Crystal size: 1-20 mm.
Crystal shape: Elongated and recrystallized in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: 100% recrystallized into foliation plane.

**SECONDARY MINERALOGY:**
Total percent: 70% to 20%.
Texture: Pseudomorphic.
Percent vein material: 5%.
Vein material: Green amphibole.

### Well-Foliated Metagabbro

### Pieces 2, 3, 7, 9, 11, 13, 22, and 23

**COLOR:** Greenish gray
**LAYERING:** Faint magmatic layering, normal to foliation.
**DEFORMATION:** Foliation more distinct. Strongly foliated pyroxene porphyroclasts.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 68%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral.
Preferred orientation: none remains.
Percent replacement: 90% with secondary plagioclase.

Clinopyroxene—Mode: 20%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: none remains.
Percent replacement: 80%. Largely replaced by green amphibole.

**SECONDARY MINERALOGY:**
Total percent: 70%.
Texture: Pseudomorphic, coronitic.
Percent vein material: 25%.
Vein material: Amphibole.

### 118-735B-2D-2 (continued)

## Poorly Foliated Metagabbro

### Pieces 17-21

**COLOR:** Greenish gray
**LAYERING:** Faint magmatic layering, normal to foliation.
**DEFORMATION:** Poorly foliated.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 65%.
- Crystal size: 1-20 mm.
- Crystal shape: Idiomorphic.
- Preferred orientation: none observed.
- Percent replacement: 80%.

- Orthopyroxene—Mode: 10%.
- Crystal size: <1 mm.
- Crystal shape: Idiomorphic.
- Preferred orientation: none observed.
- Percent replacement: 20%. Partially replaced by iron oxides.

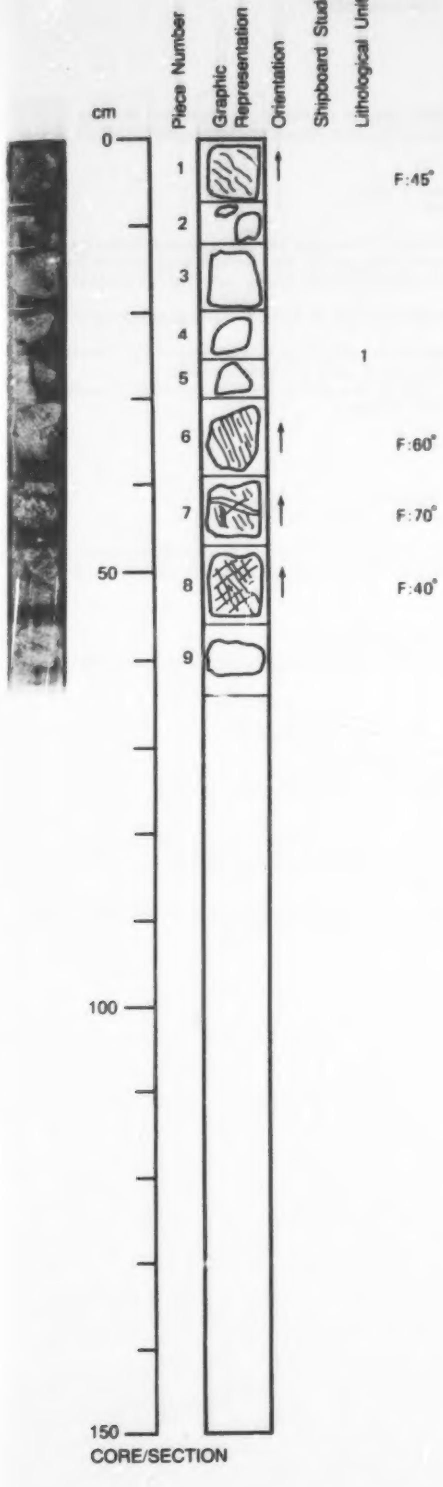
- Clinopyroxene—Mode: 22%.
- Crystal size: 1-4 mm.
- Crystal shape: Idiomorphic.
- Preferred orientation: none observed.
- Percent replacement: 50%. Green rims.

**SECONDARY MINERALOGY:**
- Total percent: 36%.
- Texture: Coronas around clinopyroxene.
- Percent vein material: No vein.
- Vein material: None.

## Mylonitic Metagabbro

### Pieces 4, 5, and 14

**COLOR:** Greenish gray
**LAYERING:** Faint magmatic layering, normal to foliation.
**DEFORMATION:** Foliation more distinct with discrete mylonitic zones, 1-2 cm thick.
**PRIMARY MINERALOGY:** Same as well-foliated gabbro. Very elongated in the plane of foliation. Crystal size is <1 mm in mylonitic zones.
**SECONDARY MINERALOGY:**
- Total percent: 20%.
- Texture: Pseudomorphic, coronitic. Carbonate-hematite pseudomorphs of olivine with talc and tremolite. Clays and iron-oxides in fractures.
- Percent vein material: 5%.
- Vein material: Clays and iron-oxides.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5
6
7
8
9
1
F:45°
F:60°
F:70°
F:40°
CORE/SECTION

## 118-735B-2D-3

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-9**

**Foliated Metagabbro**

**Pieces 1-9**

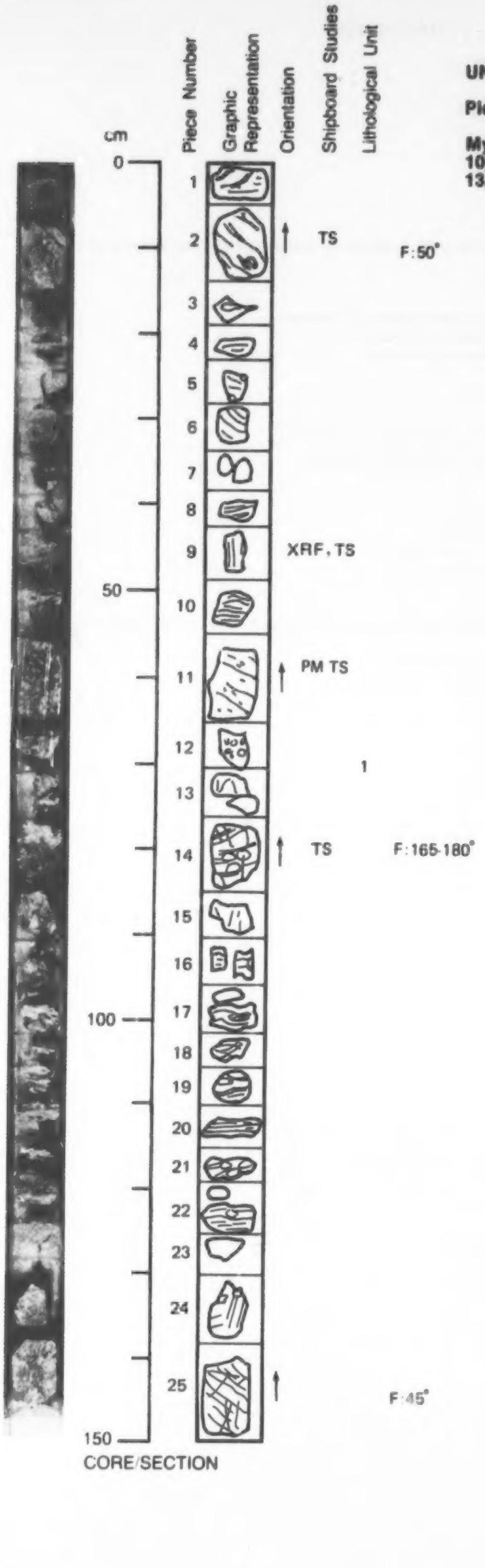
**COLOR:** Greenish gray
**LAYERING:** None
**DEFORMATION:** Foliation variable, 40%-70%, defined by stretched plagioclase and clinopyroxene.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: < 1-7 mm.
Crystal shape: Anhedral, porphyroclasts and neoblasts.
Preferred orientation: In plane of foliation.
Percent replacement: Partly recrystallized.

Clinopyroxene—Mode: 40%.
Crystal size: < 1-7 mm.
Crystal shape: Anhedral, porphyroclasts and neoblasts.
Preferred orientation: In plane of foliation.
Percent replacement: Partly replaced by amphibole.

Olivine—Mode: 10%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: 30%-50%.
Texture: Plagioclase and pyroxenes partly recrystallized. Pyroxenes partly replaced by amphibole.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-3D-1

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-25

### Mylonitic Metagabbro (Pieces 1-6 and 8), Augen Gneissic Metagabbro (Pieces 7, 9, and 10), Well-Foliated Metagabbro (Pieces 22-25), and Porphyroclastic Metagabbro (Pieces 13, 14 and 17-21)

**COLOR:** All types variably dark gray-green to white.
**LAYERING:** No primary layering apparent.
**DEFORMATION:**

**Mylonitic metagabbro:** Pieces 1-6 and 8. Fine-scale alternating layers of pyroxene and plagioclase. Piece 2 has a few lenses of pyroxene and plagioclase augen. Inclination of foliation about 50° in Piece 2; amphibolite lenses is same piece slightly S-shaped and slightly offset from main foliation.

**Augen gneissic metagabbro:** Pieces 7, 9, and 10. No oriented pieces, but similar to first group with small pyroxene augen.

**Well-foliated metagabbro:** Pieces 22-25. Inclination of foliation about 45° in Piece 25. Has stretched lens of amphibole with rounder cores of oxidized pyroxene.

**Pophyroclastic metagabbro:** Pieces 13, 14, and 17-21. Foliation near horizontal in Piece 14. Defined by stretched augen of clinopyroxene.

**PRIMARY MINERALOGY:**

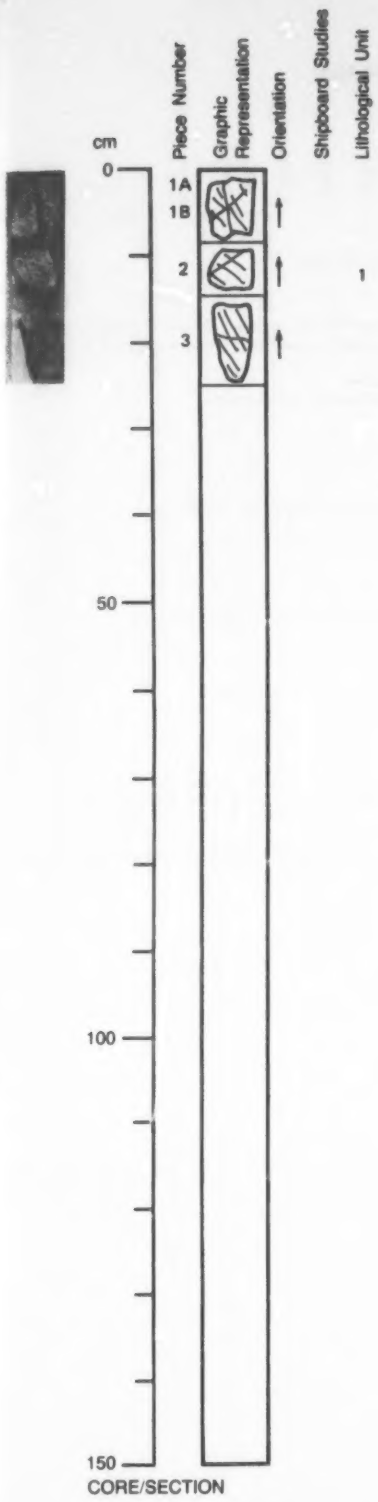
Plagioclase—Mode: 50% (originally).
Crystal size: 0.5-2.0 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent alteration: 30%-80%. Replaced by more Na-rich plagioclase.

Pyroxene—Mode: 45% (originally). Proportions of clinopyroxene/orthopyroxene are difficult to estimate because of replacement by amphibole, but orthopyroxene probably greater than clinopyroxene.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane of foliation.
Percent replacement: 50%-90%. Clinopyroxene replaced by amphibole; orthopyroxene by amphibole and orangish iron-oxide.

Olivine—Mode: 5%(?).
Crystal size: Difficult to estimate because of total alteration.
Crystal shape: Not apparent due to alteration.
Preferred orientation: Not apparent due to alteration.
Percent replacement: 100%. Replaced by dark orange-brown iron-oxide.

**SECONDARY MINERALOGY:**

Total percent: 50%-95%.
Texture: Plagioclase replaced by more Na-rich plagioclase, clinopyroxene replaced by amphibole, orthopyroxene replaced by amphibole and orangish iron-oxides, and olivine replaced by orange-brown iron-oxide.
Percent vein material: 1%-2%.
Vein material: Pieces 1, 2, 5, 11, 14-16, 19, 21, and 23-25 contain crosscutting fractures filled by amphibole. Fractures fairly random in orientation and very thin.



## 118-735B-3D-2

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1A-3

### Foliated Metagabbro (Medium- to coarse-grained)

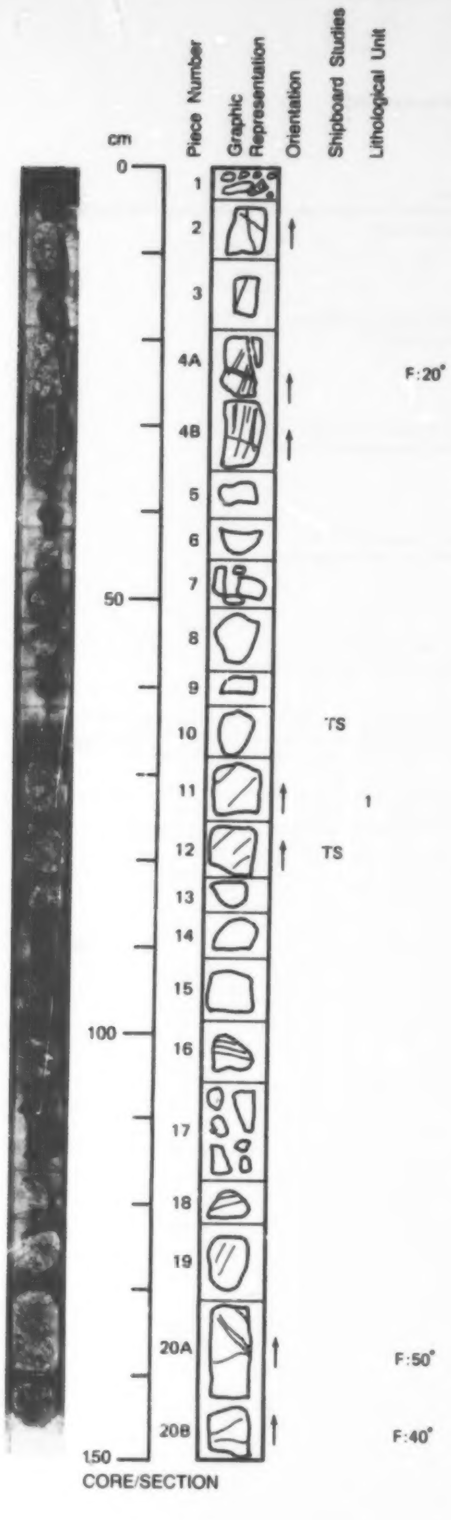
### Pieces 1A-3

**COLOR:** Gray.
**LAYERING:** No primary layering apparent.
**DEFORMATION:** Foliation defined by stretched and elongated lensoidal pyroxene and plagioclase dipping at 30° in all three oriented pieces.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Elongated in plane of foliation.
Percent replacement: Extensive albitization.

Clinopyroxene—Mode: 40%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane of foliation.
Percent replacement: Extensively altered to amphibole.

Orthopyroxene—Mode: 7%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane of foliation.
Percent replacement: 80% altered to rust-red clay mineral.

Olivine(?)—Mode: 3%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Elongate Parallel Foliation.
Percent replacement: 100% altered to rust-red clay mineral.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Extensive albitization of feldspar (milky) and alteration of pyroxene to amphibole, which forms rims or pseudomorphs around primary pyroxene. All olivine(?) appears to be totally altered to rust-red clay mineral, along with much of the orthopyroxene.
Percent vein material: 1%
Vein material: Pieces 1 and 2 contain 1-mm-thick amphibole vein nearly at right angles to foliation (inclined 53° from horizontal).
Piece 3: Contains single, 0.5-mm-thick white carbonate(?) vein lying horizontal.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4A
4B
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20A
20B
F:20°
TS
1
TS
F:50°
F:40°
CORE/SECTION

## 118-735B-4D-1

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-20B**

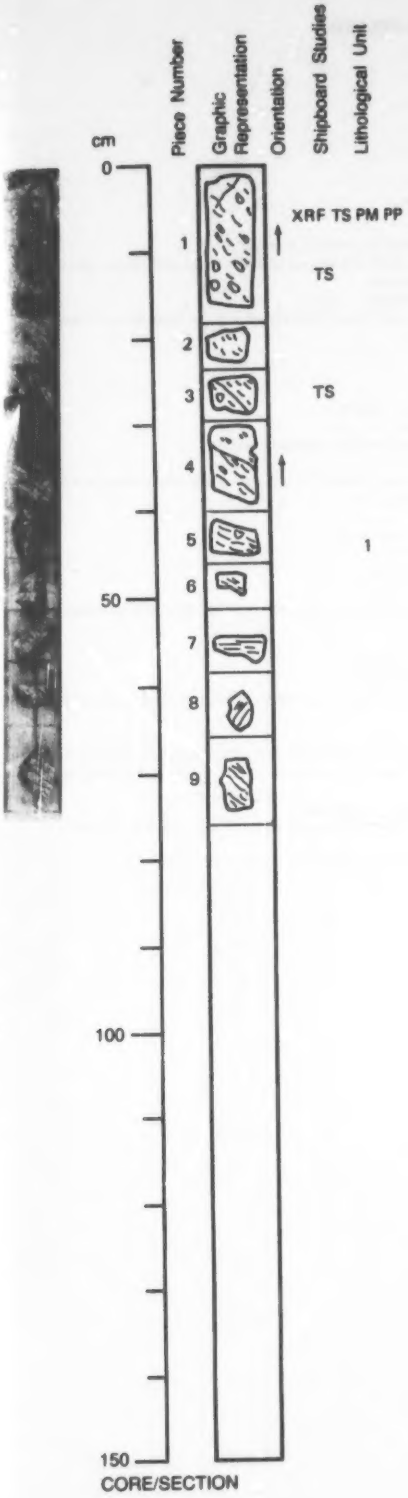
**Foliated to Mylonitized Metagabbro**

**Pieces 1-20B**

**COLOR:** Dark gray to white.
**LAYERING:** No primary layering apparent.
**DEFORMATION:**
Piece 17—Mylonitic metagabbro.
Pieces 9, 10, 15, and 16: Intensely deformed but not mylonitic. Consist of small round orthopyroxene, 1-3 mm in size, often rounded in appearance, in very fine-grained matrix of amphibole(?).
Pieces 11-13: Poorly foliated, coarse-grained.
Remaining pieces: Foliated metagabbro, medium- to fine-grained.
**PRIMARY MINERALOGY:** (original)
Plagioclase—Mode: 40%-50%.
Crystal size: 0.5-3 mm.
Crystal shape: Anhedral.
Preferred orientation: none evident.
Percent replacement: 50%-100% by milky white plagioclase (albite).

Orthopyroxene—Mode: 25%-30%(?). (Identification not definitive.)
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: none evident.
Percent replacement: 100% by amphibole and light orange-brown iron-oxide.

Clinopyroxene—Mode: 25%-30%.
Crystal size: 1-7 mm.
Crystal shape: Anhedral.
Preferred orientation: none evident.
Percent replacement: 75%-80% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: >75%.
Texture: Amphibole replaces clinopyroxene and partially replaces orthopyroxene. Orthopyroxene also replaced by light orange-brown iron-oxide. Plagioclase replaced by milky white plagioclase (albite).
Percent vein material: 2%-5%.
Vein material: Pieces 2-6 and 18-20 have fractures filled by amphibole oblique to foliation.



## 118-735B-4D-2

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-9**

**Foliated and Mylonitized Metagabbro**

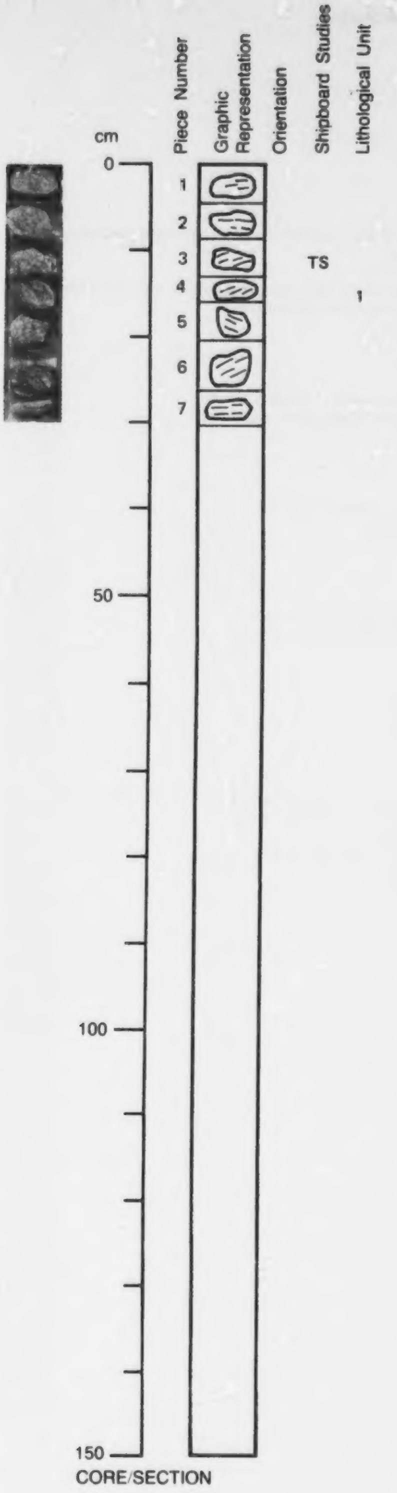
**Pieces 1-9**

**COLOR:** Gray, some black.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Foliation defined by elongated and stretched pyxorene and plagioclase with orthopyroxene augen often prominent.
Pieces 3-9: Heavily mylonitized.
Pieces 3 and 9: Have zones of dense black glassy-appearing material containing coarse orthopyroxene augen, which is mylontized ilmenite gabbro.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Often elongate parallel to foliation.
Percent replacement: Replaced by milky albite (sodic plagioclase).

Clinopyroxene—Mode: 40%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Often elongate parallel to foliation.
Percent replacement: 62% by amphibole.

Orthopyroxene—Mode: 7%.
Crystal size: 0.5-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Often elongate parallel to foliation.
Percent replacement: 66% oxidized to rust-red clay minerals.

Iron oxide(?)—Mode: 3%.
Crystal size: Not determined.
Crystal shape: Interstitial, anhedral.
Preferred orientation: none observed.
Percent alteration: 0%.
**SECONDARY MINERALOGY:**
Total percent: 29%.
Texture: Plagioclase extensively altered to milky albite. Pyroxene altered to or rimmed by amphibole. Orthopyroxene oxidized to rust-red clay minerals.
Percent vein material: Not determined.
Vein material: Amphibole, occuring in veins up to 3 mm thick.
**COMMENTS:** Pieces 1 and 2: Gneissic gabbro.
Pieces 3-9: Mylonitized metagabbro.
Pieces 3 and 4: Contain mylonitic oxide-rich zones.



**118-735B-5D-1**

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-7**

**Mylonitic Metagabbro**

**Pieces 1-7**

**COLOR:** Gray, dark gray, speckled rust brown.
**LAYERING:** None remaining, if ever present.
**DEFORMATION:** All pieces profoundly foliated on a very fine scale.
Pieces 1-3 and 6: Foliation is more distinct because of mafic/felsic alternation, also easier to see on rounded rather than cut surfaces.
Pieces 4 and 7: Especially finely foliated.
Pieces 1 and 7: Founded by upper and lower foliation surfaces; all other pieces show foliation inclined to flat surfaces on pieces.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: <2 mm.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Marks foliation.
Percent replacement: 50% with milky feldspar (probably albite).

Clinopyroxene—Mode: Total pyroxenes, about 40% (difference between orthopyroxene and clinopyroxene; see thin section description).
Crystal size: <2 mm.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Marks foliation.
Percent replacement: 75% by amphibole.

Orthopyroxene—Mode: See clinopyroxene. Pieces 1 and 6: Small relict orthopyroxene (altered) porphyroclasts (5% of each piece).
Crystal size: <2 mm.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Marks foliation.
Percent replacement: 100% by orange-brown secondary minerals (obviously partly iron-oxides).
**SECONDARY MINERALOGY:**
Total percent: >30%.
Texture: Mostly green amphibole after clinopyroxene, and milky feldspar (probably albite) after plagioclase. Orthopyroxene (minor) replaced by orange-brown secondary minerals (obviously partly iron-oxides).
Percent vein material: Not determined.
Vein material: Small (<<1 mm) veins filled with amphibole cut mylonite and fill cracks in plagioclase.
**COMMENT:** The primary igneous mineralogy is recrystallized during deformation.

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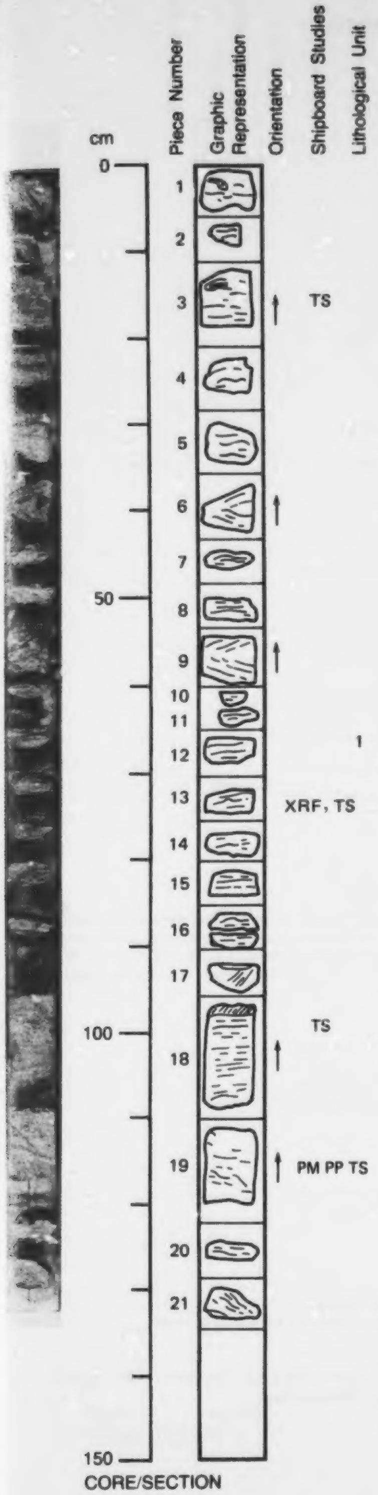


## 118-735B-6D-1

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-21

### Foliated Metagabbro (Partly Mylonitic)

### Pieces 1-16, and 18 (bottom)-21

**COLOR:** Gray to dark gray with reddish brown dots.
**LAYERING:** No primary layering apparent.
**DEFORMATION:** Foliation defined by fine-grained mylonitic bands and less deformed foliated porphyroclastic bands. Porphyroclasts are clinopyroxene, orthopyroxene, and plagioclase.
Pieces 4 and 13: Mylonitic gabbro.
Pieces 1-3, 5-12, 14-16, most of 18, 19 (with mylonitic band), 20, and 21: Gneissic to augen gneissic gabbro.
Pieces 6, 9, 12, and 14: Have amphibole vein parallel/subparallel to the foliation.
Pieces 17 and 18: Have a dark gray part (metabasalt?). The contacts with foliated gabbro are present at the top of Piece 17 and ~1 cm from the top of Piece 18. The contact in Piece 17 is probably the upper and that in Piece 18 is the lower contact of basalt(?) and gabbro.
Piece 3: Contains an isoclinal fold.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Mostly neoblast, porphyroclast <3 mm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: Moderate by sodic plagioclase(?).

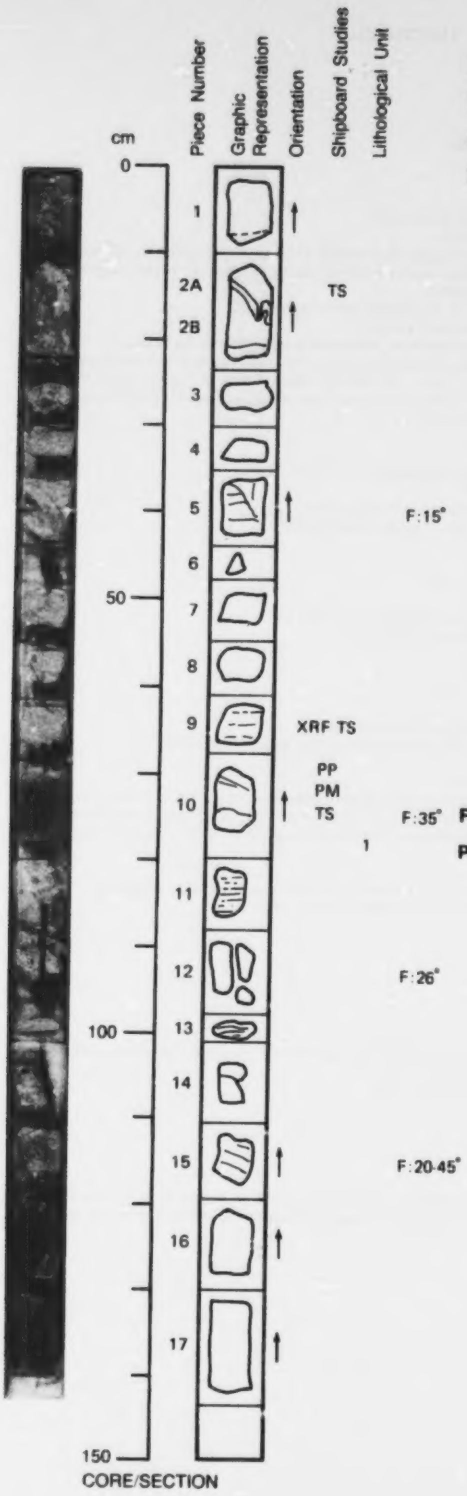
Clinopyroxene—Mode: 40%.
Crystal size: Porphyroclast <1 cm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: 50%-80% by amphibole.

Orthopyroxene—Mode: ~5%.
Crystal size: Porphyroclast <1 cm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: 100%-90% oxidized to reddish mineral (iron oxide).
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Plagioclase is altered into white sodic plagioclase, especially in Pieces 3 and 7-9. Clinopyroxene is altered to amphibole. Clinopyroxene porphyroclasts are surrounded by amphibole aggregates. Orthopyroxene is oxidized to reddish mineral, probably ferric oxyhydroxide + hematite.
Percent vein material: 2%.
Vein material: Pieces 6, 9, 12 and 14 contain common amphibole veins (or layers).
Piece 7: Veins are up to 4 mm thick, cutting foliation at 30°

### Mylonite

### Pieces 17 and 18 (top)

**COLOR:** Dark gray.
**LAYERING:** No layering.
**DEFORMATION:** Foliation is apparent by parallel arrangement of 1 mm long laths (plagioclase(?) or amphibole(?)) and is horizontal at ~20°.
**PRIMARY MINERALOGY:** Too altered to determine.
**SECONDARY MINERALOGY:**
Total percent: Extensive.
Texture: Not determined.
Percent vein material: None.
Vein material: None.
**NOTES:** Because of extensive metamorphism, the protolith is hard to determine. It is probably microgabbro. Contact of mylonite with adjacent metagabbro is subparallel to foliation.



## 118-735B-7D-1

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-17

### Gabbro

### Piece 1, 16, and 17

**COLOR:** Dark gray.
**LAYERING:** Massive.
**DEFORMATION:** Minor.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 1-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: None.
Percent replacement: Fresh.

Clinopyroxene—Mode: 39%.
Crystal size: 1-20 mm.
Crystal shape: Anhedral, incipient oikocrysts.
Preferred orientation: None.
Percent replacement: ~5% by amphibole.

Olivine—Mode: 5%.
Crystal size: 0.5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: ~10% by tremolite + chlorite.

Orthopyroxene—Mode: 1%.
Crystal size: ~1 mm.
Crystal shape: Anhedral
Preferred orientation: None.
Percent replacement: 5% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replacing olivine and pyroxene.
Percent vein material: 1%.
Vein material: Amphibole.

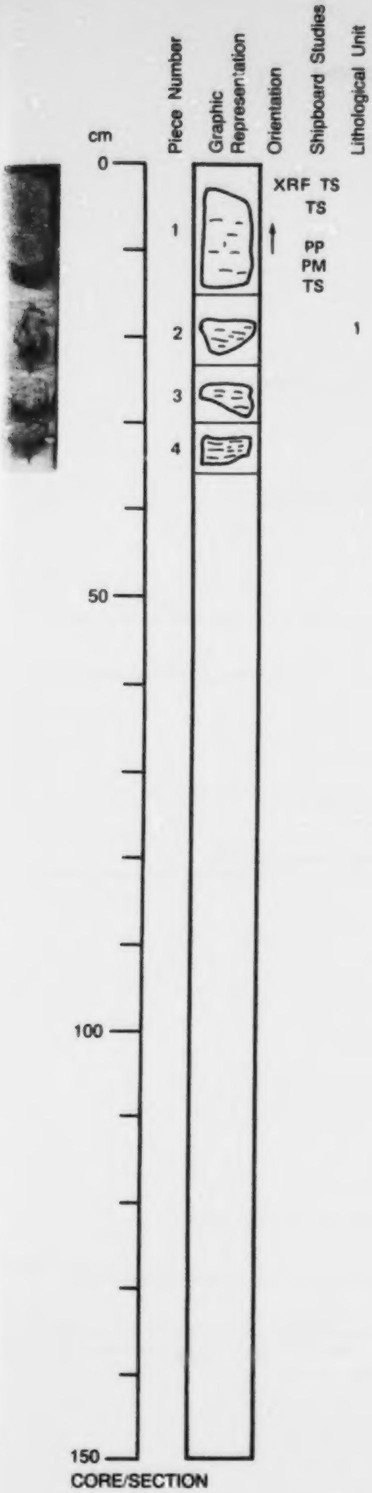
### Foliated Metagabbro

### Pieces 2-15

**COLOR:** Gray to dark gray with reddish brown dots.
**LAYERING:** No primary layering.
**DEFORMATION:** Foliation defined by fine-grained mylonitic bands and less deformed foliated porphyroclastic bands. Porphyroclasts are clinopyroxene, orthopyroxene, and plagioclase. Pieces 2A and 2B: Gneissic metagabbro containing isoclinal holds. Pieces 3, 12, 14, and 15: Porphyroclastic Metagabbro. Pieces 4, 5, 9, and 10: Well-foliated metagabbro. Pieces 7 and 8: Poorly-foliated metagabbros.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Mostly neoblast, porphyroclast <3 mm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: Moderate by sodic plagioclase(?).

Clinopyroxene—Mode: 40%.
Crystal size: Porphyroclast <1 cm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: 50%-80% by amphibole.

Orthopyroxene—Mode: ~5%.
Crystal size: Porphyroclast <1 cm.
Crystal shape: Anhedral.
Preferred orientation: No clear preferred orientation.
Percent replacement: 100%-90% oxidized to reddish mineral (iron oxide).
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Plagioclase is altered into white sodic plagioclase. Clinopyroxene is altered to amphibole. Orthopyroxene is oxidized to reddish mineral.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-7D-2

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-4

### Gabbro

### Piece 1

**COLOR:** Dark gray.
**LAYERING:** Massive.
**DEFORMATION:** Minor.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 55%.
  Crystal size: 1-10 mm.
  Crystal shape: Subhedral-euhedral.
  Preferred orientation: None.
  Percent replacement: Fresh.

- Clinopyroxene—Mode: 39%.
  Crystal size: 1-20 mm.
  Crystal shape: Anhedral, incipient oikocrysts.
  Preferred orientation: None.
  Percent replacement: ~5% by amphibole.

- Olivine—Mode: 5%.
  Crystal size: 0.5-10 mm.
  Crystal shape: Anhedral.
  Preferred orientation: None.
  Percent replacement: ~10% by tremolite + chlorite.

- Orthopyroxene—Mode: 1%.
  Crystal size: ~1 mm.
  Crystal shape: Anhedral
  Preferred orientation: None.
  Percent replacement: 5% by amphibole.

**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replacing olivine and pyroxene.
Percent vein material: 1%.
Vein material: Amphibole.

**COMMENTS:** Gabbro continued from Section 118-735B-7D-1.

### Porphyroclastic Metagabbro

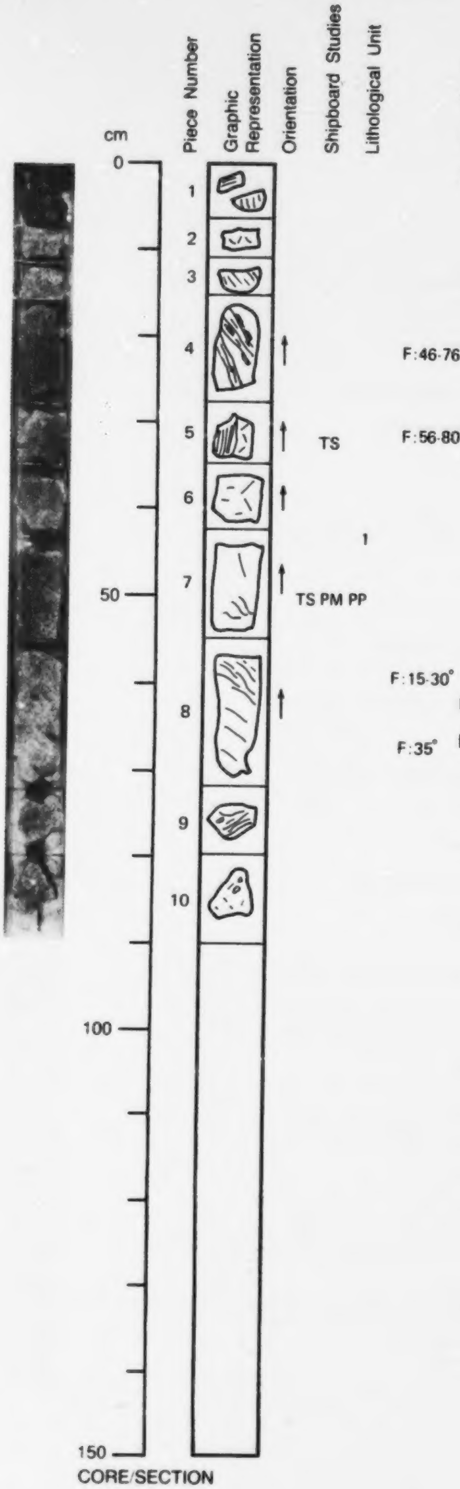
### Pieces 2-4

**COLOR:** Gray to dark gray with reddish brown dots.
**LAYERING:** No primary layering.
**DEFORMATION:** Piece 4: Has mylonitic band.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 55%.
  Crystal size: Mostly neoblast, porphyroclast <3 mm.
  Crystal shape: Anhedral.
  Preferred orientation: No clear preferred orientation.
  Percent replacement: Moderate by sodic plagioclase(?).

- Clinopyroxene—Mode: 40%.
  Crystal size: Porphyroclast <1 cm.
  Crystal shape: Anhedral.
  Preferred orientation: No clear preferred orientation.
  Percent replacement: 50%-80% by amphibole.

- Orthopyroxene—Mode: ~5%.
  Crystal size: Porphyroclast <1 cm.
  Crystal shape: Anhedral.
  Preferred orientation: No clear preferred orientation.
  Percent replacement: 100%-90% oxidized to reddish mineral (iron oxide).

**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Plagioclase is altered into white sodic plagioclase. Clinopyroxene is altered to amphibole. Orthopyroxene is oxidized to reddish mineral.
Percent vein material: Not determined.
Vein material: Not determined.



118-735B-8D-1

## UNIT 1: FOLIATED METAGABBRO

**Pieces 1-10**

**Porphyroclastic Metagabbro (see Unit 1)**

**Pieces 1, 4, 8, and 9**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Extensive, porphyroclastic textures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 0.1-5 mm.
Crystal shape: Anhedral porphyroclasts.
Preferred orientation: Porphyroclasts aligned in foliation.
Percent replacement: Not determined.

Pyroxene—Mode: 40%
Crystal size: 0.5-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Porphyroclasts aligned in foliation.
Percent replacement: Not determined.

Olivine/orthopyroxene—Mode: 8%.
Crystal size: 1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% replaced by Fe-oxyhydroxides and clays mostly in piece 9.
**SECONDARY MINERALOGY:**
Total percent: 90%.
Texture: 10% pyroxene porphyroclasts, rest is amphibolitized. Plagioclase is albitized.
Percent vein material: 0%.
Vein material: None.

**Massive Gabbro**

**Pieces 2, and 5-7**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Piece 5—half of piece is strongly foliated metagabbro.
Deformation increases downward; grain size decreases in bottom half of piece to poorly foliated gabbro.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 55%.
Crystal size: Up to 0.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Weak foliation.
Percent replacement: Minor.

Plagioclase—Mode: 40%.
Crystal size: Up to 0.5 cm.
Crystal shape: Anhedral.
Preferred orientation: none observed.
Percent replacement: Minor.

Olivine or orthopyroxene—Mode: 5%.
Crystal size: 0.5-2 mm.
Crystal shape: Anhedral.
Preferred orientation: none observed.
Percent replacement: Extensively pseudomorphed by clay minerals.
**SECONDARY MINERALOGY:**
Total percent: 8%.
Texture: Orthopyroxene and olivine altered to clay minerals. Some amphibole after clinopyroxene.
Percent vein material: 3%.
Vein material: White, prehnite(?) and albite(?). Size not determined, <3 mm certainly.
**COMMENTS:** Piece 4: Is massive in one corner. Contact in piece is probably continuous with contact in Piece 5, though pieces are flipped around core axis.

## 118-735B-8D-1 (continued)

### Massive Altered Gabbro

### Piece 10

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak, if any, foliation.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 52%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%-20% albitized(?).

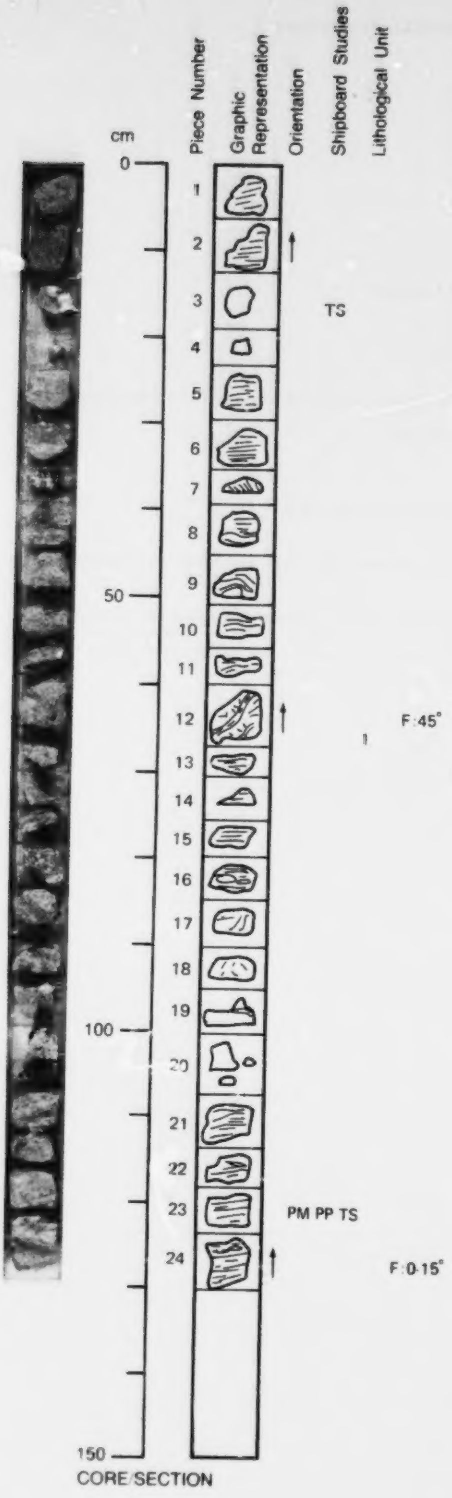
Clinopyroxene—Mode: 40%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None
Percent replacement: Extensively altered to amphibole, many have dark chloritic rims.

Olivine or orthopyroxene(?)—Mode: 8%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% by clay minerals/hematite.

**SECONDARY MINERALOGY:**

Total percent: 35%.
Texture: Chlorite rims on pyroxene. Oxidative pseudomorphs of olivine or orthopyroxene. Some albitization of plagioclase.
Percent vein material: 5%.
Vein material: <1 mm, no consistent orientation. Filled by plagioclase and prehnite.

**COMMENTS:** The orange pseudomorphs in Cores 118-735B-7D and -8D are smaller, more anhedral, with no cleavage, compared to earlier samples—possibly a transition to olivine gabbro. Seem to be fewer of the green amphibole-white albite alteration zones.



118-735B-9D-1

## UNIT 1: FOLIATED METAGABBRO

### Pieces 1-24

### Mylonitic Metagabbro to Well-Foliated Metagabbro (Pieces 1, 2, 6, 8-15, and 21-24) and Porphyroclastic Metagabbro (Pieces 5 and 7)

**COLOR:** Gray-green.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic with clinopyroxene, plagioclase clasts, and some mylonitic zones 0.5-1 mm thick (Pieces 6, 21, 23, and 24). Pieces 5 and 7 contain 10%-15% pyroxene porphyroclasts.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <1-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Augen parallel to foliation.
Percent replacement: 20% to <1 mm neoblasts.

Clinopyroxene—Mode: 45%.
Crystal size: <1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Lenses parallel to foliation.
Percent replacement: 40% to amphibole, 40% to <1 mm neoblasts.

Olivine—Mode: <5%.
Crystal size: 0.5-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 80% to clay, hematite.
**SECONDARY MINERALOGY:**
Total percent: 50%.
Texture: Hematite/smectite after olivine, green amphibole after clinopyroxene. Piece 7: Very oxidized with orthopyroxene altered to orange clayey pseudomorphs.
Percent vein material: No prominent veins noted.
Vein Material: Not determined.

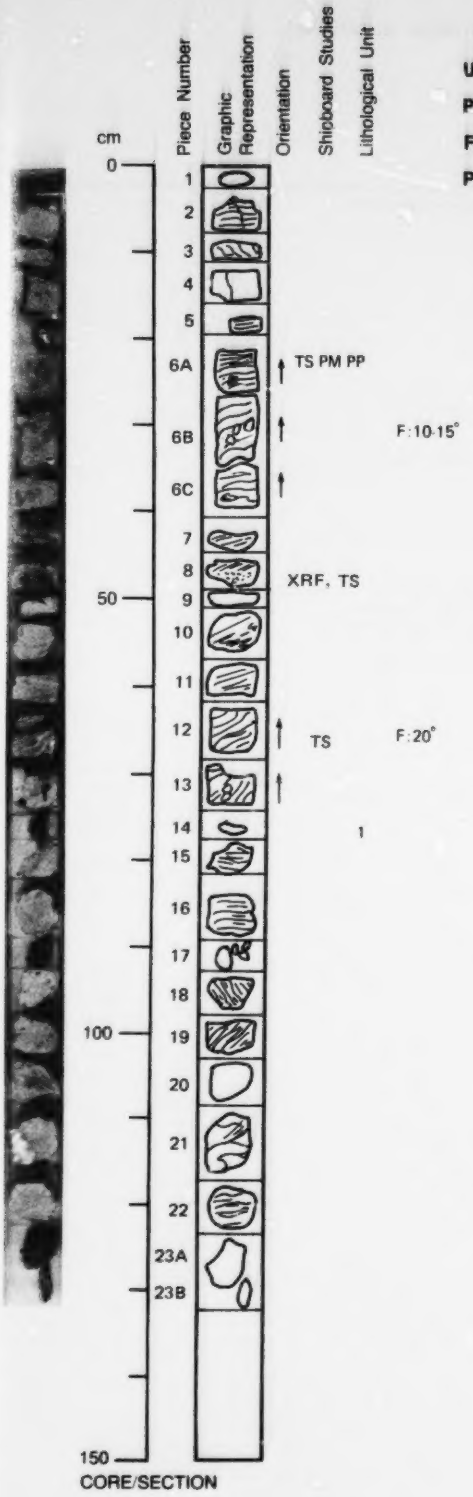
### Equigranular Amphibolitized Gabbro

### Piece 3

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** No clearly defined deformation.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 60%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: ≤5% in places replaced by amphibole.

Plagioclase—Mode: 35%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5% replaced in part by amphibole.

Olivine or orthopyroxene—Mode: 5%.
Crystal size: 1-2 mm, one to 4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 90% to clay minerals.
**SECONDARY MINERALOGY:**
Total percent: Variable, on one side, 80%, on the other, 15%.
Texture: On the more heavily altered side, there is a lot of amphibole and perhaps chlorite after clinopyroxene and maybe plagioclase. On the less altered side, the rock contains more igneous minerals.
Percent vein material: No prominent veins noted.
Vein material: Not determined.



## 118-735B-10D-1

### UNIT 1: FOLIATED METAGABBRO

### Pieces 1-23B

### Foliated and Porphyroclastic Metagabbro

### Pieces 1-23B

**COLOR:** Generally darker than in first few cores due to less albitization of plagioclase. Dark gray, mottled by orangish streaks of oxidation.
**LAYERING:** None.
**DEFORMATION:** Defined by stretched and elongated plagioclase and orangish oxidation streaks along with layers of amphibole. Porphyroclasts range from 2-3 mm up to 1 cm in Pieces 6A-C.
Pieces 11, 14, and 15: Well-foliated (very fine layers) metagabbro. Similar compositionally to above group, but no porphyroclasts.
Pieces 7, 9, and 10: Foliated, but foliation is less distinct than usual because of less alteration. Foliation is defined by elongate masses of small crystals of plagioclase and pyroxene. Texture is overall very fine-grained.
Piece 8: Contains a contact between this very fine-grained foliated texture and a massive gabbro.
Pieces 18 and 20: Poorly foliated massive gabbro.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 40%.
Crystal size: Few mm to 1 cm.
Crystal shape: Anhedral—elongate in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: Partially replaced by amphibole 80%-20%.

Plagioclase—Mode: 35%.
Crystal size: Few mm to 1 cm.
Crystal shape: Anhedral—elongate in plane of foliation.
Preferred orientation: Plane of foliation.
Percent replacement: 80%-20%.

Olivine—Mode: 25% (may include some opx).
Crystal size: >1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60%-100% replaced by orange brown alteration phase.
**SECONDARY MINERALOGY:**
Total percent: 20-30%. Locally up to 80%.
Texture: Consists mostly of replacement of pyroxene by amphibole.
Orthopyroxene is replaced by orange brown oxidation minerals (probably clay minerals + iron oxides). Pieces 12, 22, and 23: Minor replacement of plagioclase by sodic plagioclase.
Percent vein material: Not determined.
Vein material: No amphibole veins.

**118-735B-10D-1 (continued)**

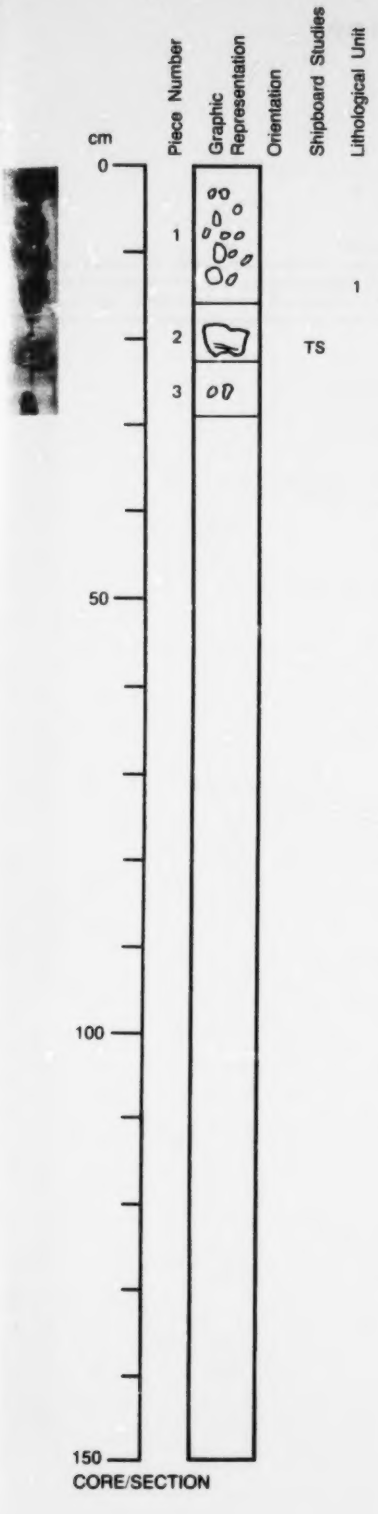
## Poorly Foliated to Massive Gabbro

### Pieces 4 and 16-20

**COLOR:** Gray with orange pseudomorphs.
**LAYERING:** None.
**DEFORMATION:** Very slight. Piece 16: Rounded plagioclase-clinopyroxene porphyroclasts. Piece 17: More foliated with a distinct orange oxidized zone.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%, fresh.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%, fresh.

Orthopyroxene—Mode: 5%-8%, 0% in Piece 16.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% to clayey pseudomorphs.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Orthopyroxene completely replaced by clayey/hematite clots. Probably some amphibole on clinopyroxene.
Pieces 17 and 19: Some albitization of plagioclase.
Percent vein material: 1%-2%.
Vein material: White of undetermined composition. <3 mm thick.



**118-735B-10D-2**

**UNIT 1: FOLIATED METAGABBRO**

**Pieces 1-3**

**Poorly Foliated Metagabbro to Foliated Metagabbro**

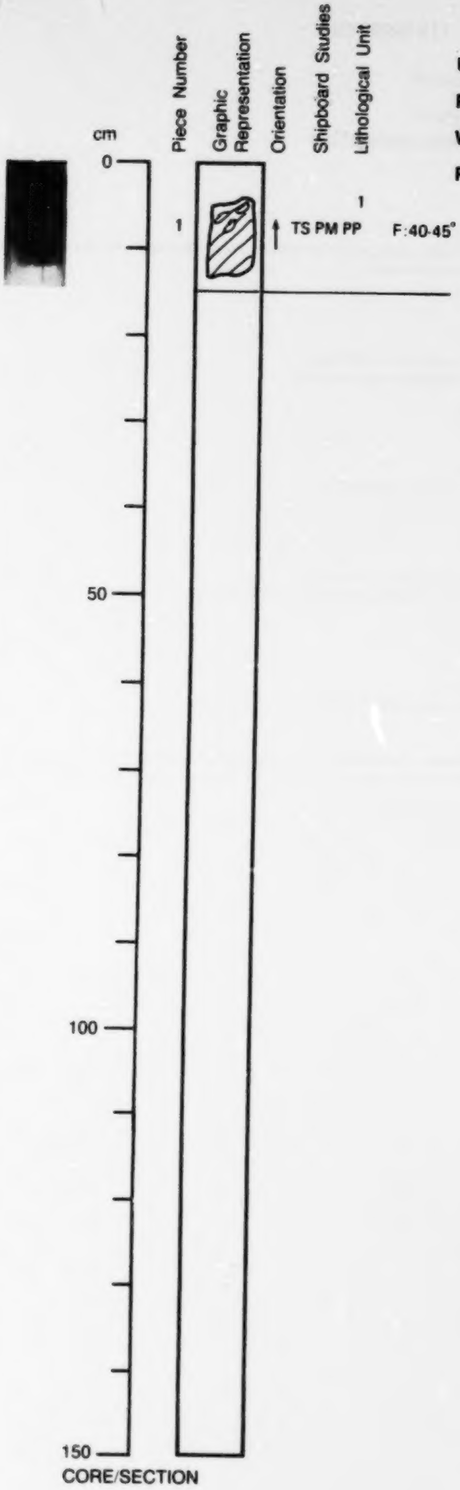
**Pieces 1-3**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Poorly foliated to foliated metagabbro on bottom. Porphyroclastic—localized mylonitic zones and plagioclase and olivine augen.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Lenses parallel to foliation.
Percent replacement: 25% recrystallized neoblasts.

Clinopyroxene—Mode: 40%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%-15% by amphibole.

Olivine—Mode: 10%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Lenses parallel to foliation.
Percent replacement: 50% by tremolite, magnetite, and iron-oxide.

Orthopyroxene: Mode: <1%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred Orientation: None.
Percent replacement: 70% by tremolite(?), only fragments remain.
**SECONDARY MINERALOGY:**
Total percent: 15%
Texture: Tremolite and hematite after olivine, amphibole after clinopyroxene—some magnetite after clinopyroxene. Small anhedral pseudomorphs (<1%) that are orange to greenish may be olivine replacements.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
1
TS PM PP
F:40-45°
CORE/SECTION

118-735B-11D-1

## UNIT 1: FOLIATED METAGABBRO

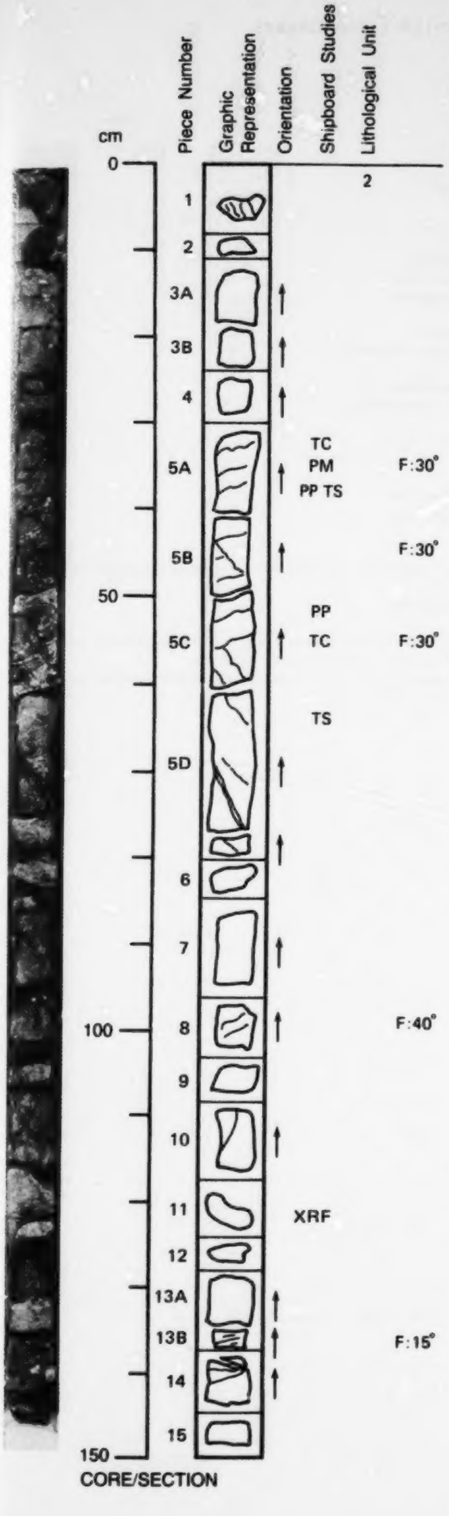
**Piece 1**

**Well-Foliated Metagabbro**

**Piece 1**

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** Well-defined foliation, dipping 40-45°.
Foliation defined by flattened porphyroclasts and fine-grained bands. Deformation gradient present in the sample, with grain size decreasing from top to bottom. Porphyroclastic metagabbro in the part (pyroxene porphyroclasts up to 1 cm); well-foliated, very fine-grained metagabbro with mylontic bands in the lower part (pyroxene porphyroclasts <1 mm).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1 cm.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Marks foliation.
Percent replacement: 30% by sodic plagioclase.

Clinopyroxene—Mode: 40%.
Crystal size: <1 mm (lower part), <1 cm (upper part).
Crystal shape: Flattened porphyroclasts.
Preferred orientation: Marks foliation.
Percent replacement: 5% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: About 5%.
Texture: Pseudomorphic amphibole replacing pyroxene.
Percent vein material: No visible veins.
Vein material: none.



118-735B-12R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-15**

### Mylonitic Gabbro

**Pieces 1 and 2**

**COLOR:** Gray.
**LAYERING:** Massive.
**DEFORMATION:** Very fine-grained bands of recrystallized clinopyroxene and lesser amounts of recrystallized plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 0.1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: <5% locally by prehnite.

Clinopyroxene—Mode: 35%.
Crystal size: Clinopyroxene porphyroclasts up to 7 mm but generally 0.1 mm.
Crystal shape: Anhedral, stretched.
Preferred orientation: Not determined.
Percent replacement: <5% locally by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Prehnite locally replaces plagioclase (<5%). Amphibole partially replaces clinopyroxene (<5%).
Percent vein material: Not determined.
Vein material: Not determined.

### Porphyroclastic Pegmatoidal Gabbro

**Pieces 3-5C, and 8**

**COLOR:** Gray.
**LAYERING:** Massive.
**DEFORMATION:** Stretched clinopyroxene and plagioclase define foliation. Inclination of foliation varies from 15°-40°. Clinopyroxene and plagioclase are recrystallized.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: Porphyroclasts up to 2.5 cm.
Crystal shape: Anhedral, stretched.
Preferred orientation: Not determined.
Percent replacement: Replaced by prehnite.

Clinopyroxene—Mode: 35%.
Crystal size: Porphyroclasts up to 2.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 15% by amphibole.

Olivine—Mode: Trace.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 15%-20%.
Texture: 15% green amphibole replacing clinopyroxene and in veins perpendicular to foliation. Prehnite replacing plagioclase and filling some late fractures.
Percent vein material: Not determined.
Vein material: Amphibole in veins perpendicular to foliation. Prehnite in late fractures.
**COMMENTS:** Plagioclase-rich zone (approximately 75% plagioclase) occurs at the bottom of Piece 5B and at the top of Piece 5C.

118-735B-12R-1 (continued)

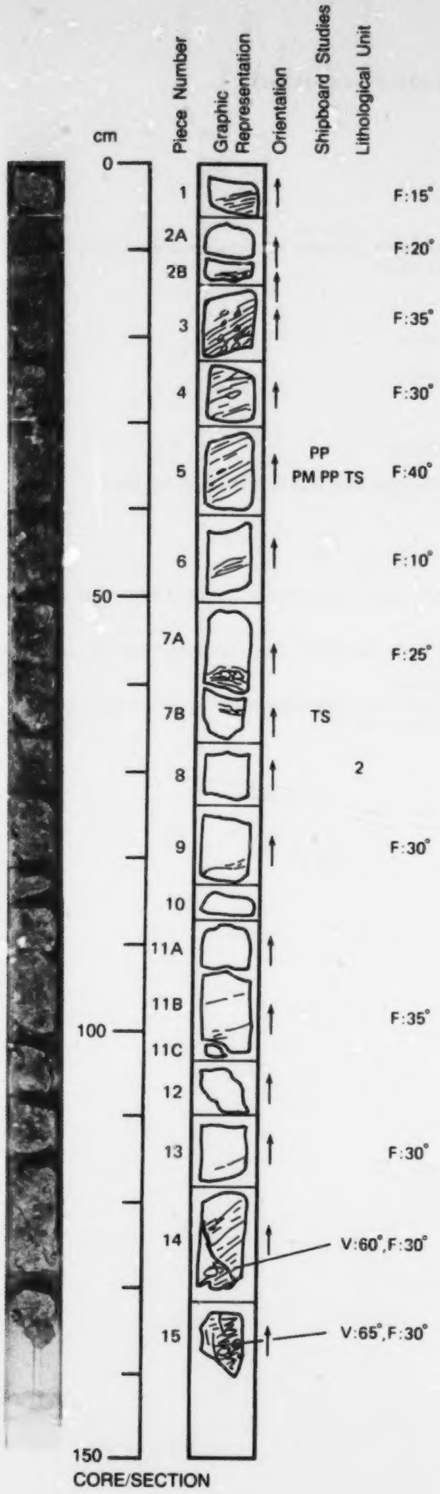
**Olivine-Bearing Gabbro**

**Pieces 6, 7, and 9-15**

**COLOR:** Gray.
**LAYERING:** None, massive.
**DEFORMATION:** Local mylonitic bands.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-12 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: 1% by prehnite.

Clinopyroxene—Mode: 32%-40%.
Crystal size: 2-7 mm. Up to 3 cm in Piece 6.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 2%-5% by amphibole.

Olivine—Mode: Trace-8% (Piece 15).
Crystal size: 2-11 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 3%-6%.
Texture: Prehnite 1% replaces plagioclase. Amphibole 2%-5% replaces clinopyroxene, and fills late stage veins.
Percent vein material: Not determined.
Vein material: Amphibole.
**COMMENTS:** Pieces 7 and 9: Sheared zones with sharp contacts to massive undeformed gabbro.
Piece 12: Massive gabbro with contact to porphyroclastic gabbro.
Piece 14: Contact between coarse-grained massive gabbro and medium-grained gabbro.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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11A
11B
11C
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14
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PP
PM PP TS
TS
2
F:15°
F:20°
F:35°
F:30°
F:40°
F:10°
F:25°
F:30°
F:35°
F:30°
V:60°,F:30°
V:65°,F:30°
CORE/SECTION

**118-735B-12R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-15**

### Weakly Foliated Metagabbro (Pieces 1-2B (top), 6, and 11B) and Porphyroclastic Metagabbro (Pieces 2B (bottom), 3-5, 14, 15)

**COLOR:** Gray with brown patches (altered olivine crystals) and/or white layer (altered plagioclase).
**LAYERING:** None, massive.
**DEFORMATION:** Distinct foliation defined by stretched plagioclase, olivine, and pyroxene crystals.
Large clinopyroxene porphyroclasts are dominant.
Recrystallized plagioclase shows discontinous layering with less than a few mm thickness.
The foliation inclines 10°-40°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 70%.
Crystal size: <0.8 cm (porphyroclastic grains).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight-moderate, replaced by sodic plagioclase.

Clinopyroxene—Mode: 10%.
Crystal size: <2 cm (porphyroclastic grains).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50%. Amphibole replaces grain margins.

Olivine—Mode: 15%.
Crystal size: <0.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Almost 60%-100%. Amphibole replaces grain margins. Most olivine is oxidized.

Orthopyroxene—Mode: 5%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred Orientation: None.
Percent replacement: 50%-100% oxidized.
**SECONDARY MINERALOGY:**
Total percent: Moderate.
Texture: Green amphibole replaces olivine and clinopyroxene crystal margins. Most olivine crystals are oxidized. Piece 1: Secondary sulfides present.
Percent vein material: Variable.
Vein material: Pieces 14 and 15—Amphibole vein runs almost perpendicular to the foliation (60°-65° inclination). The vein is 0.5 to 4 mm wide. Piece 11B: Thin white albite vein inclined at 10°.

## 118-735B-12R-2 (continued)

### Olivine-Bearing Gabbro

### Pieces 7A-11A, and 11C-13

**COLOR:** Gray to dark gray.
**LAYERING:** None, massive.
**DEFORMATION:** Partly foliated (Pieces 9 and 13). Inclination 30°. The foliation is defined by stretched plagioclase, orthopyroxene, and olivine.
**PRIMARY MINERALOGY:**

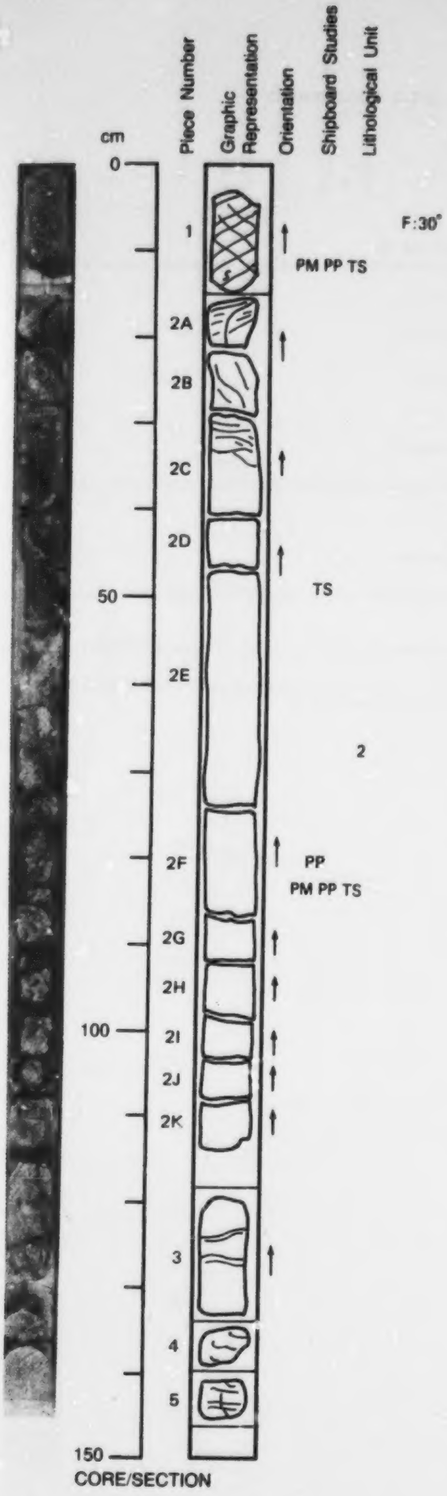
Plagioclase—Mode: 50%.
Crystal size: 0.2-1.5 cm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: 0.2-2.0 cm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Replaced by green amphibole, percentage not measured.

Olivine—Mode: 5%.
Crystal size: 0.3-1.0 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: Replaced by serpentinite or chlorite, percentage not measured.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Amphibole replaces clinopyroxene from the margins. Olivine is replaced by serpentine or chlorite along mesh of cracks.
Percent vein material: Not determined.
Vein material: Amphibole along microfault (every piece). Pieces 8-10: 0.5-mm-thick, white prehnite or albite vein inclines at less than 10°.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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PM PP TS
F:30°
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2B
2C
2D
TS
50
2E
2
2F
PP
PM PP TS
2G
2H
100
2I
2J
2K
3
4
5
150
CORE/SECTION

**118-735B-12R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-5**

### Foliated Gabbro

**Pieces 1-2C (top), 4, and 5**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Foliated gabbro cut green by amphibole veins that are perpendicular to the foliation (Piece 1). Foliated gabbro with gneissic banding on top and bottom (Pieces 2A-2C). Pieces 4 and 5: Foliated metagabbro crosscut by amphibole veins.
**PRIMARY MINERALOGY:** Probably same as fresh gabbro below.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Albite replaces plagioclase; green amphibole replaces pyroxene. 20% green amphibole.
Percent vein material: Not determined.
Vein material: Amphibole.

### Olivine-Bearing Gabbro

**Pieces 2C (bottom)-3**

**COLOR:** Medium gray, mottled.
**LAYERING:** Massive.
**DEFORMATION:** Undeformed.
Piece 3: Discrete mylonite bands
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 43%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 2% (enriched in Piece 2C).
Crystal size: 3-4 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Green amphibole (about 5%) dispersed and filling veins.
Percent vein material: Not determined.
Vein material: Green amphibole.
**COMMENTS:** Coarse-grained.

118-735B-12R-3 (continued)

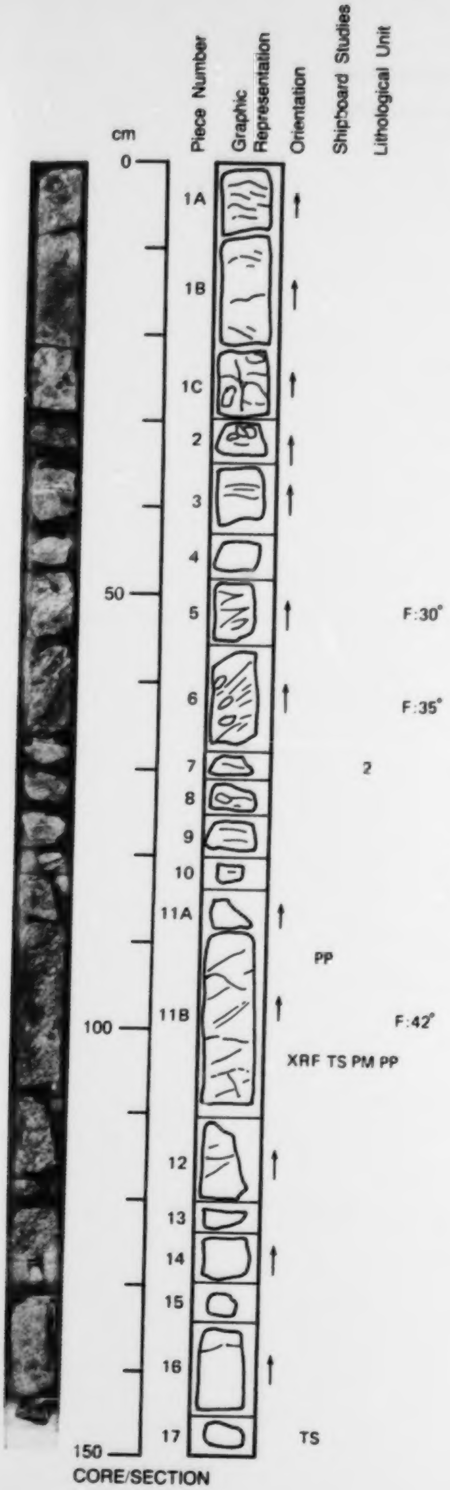
**Olivine-Bearing Gabbro**

**Pieces 7-11A, 12, and 13**

**COLOR:** Gray to dark gray.
**LAYERING:** None, massive.
**DEFORMATION:** Partly foliated (Pieces 9 and 13).
Inclination 30°. The foliation is defined by stretched plagioclase, orthopyroxene, and olivine.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 0.2-1.5 cm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Not measured.

Clinopyroxene—Mode: 45%.
Crystal size: 0.2-2.0 cm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Replaced by green amphibole, percentage not measured.

Olivine—Mode: 5%.
Crystal size: 0.3-1.0 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: Replaced by serpentinite or chlorite, percentage not measured.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replaces clinopyroxene from the margins. Olivine is replaced by serpentine or chlorite along mesh of cracks.
Vein material: Amphibole present along microfault (every piece). Pieces 8-10: 0.5-mm-thick, white prehnite or albite vein inclines at less than 10°.



118-735B-13R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-17

### Olivine-Bearing Metagabbro (with Gneissic and Mylonitic Bands)

### Pieces 1-10, and 17

**COLOR:** Pale to medium greenish gray.
**LAYERING:** None.
**DEFORMATION:** Pieces 1A-B, 3, and 5: discrete gneissic bands.
Pieces 1B (bottom), 1C, and 4: Brecciated.
Pieces 3, 6, and 8: Large clinopyroxene porphyroclasts.
Piece 17: Foliated, crosscut by five white veins.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: 50% by secondary plagioclase.

Clinopyroxene—Mode. 45%
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: Less than 15%.

Olivine—Mode: 5%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Partly oxidized to brownish material.
**SECONDARY MINERALOGY:**
Total percent: Less than 20%.
Texture: Green amphibole forms about 15% of the rock.
Olivine is oxidized to brownish material. Some sulfides.
Percent vein material: Not determined.
Vein material: Few white veinlets that could be carbonate. Horneblende veins at 55°, also vertical veins.

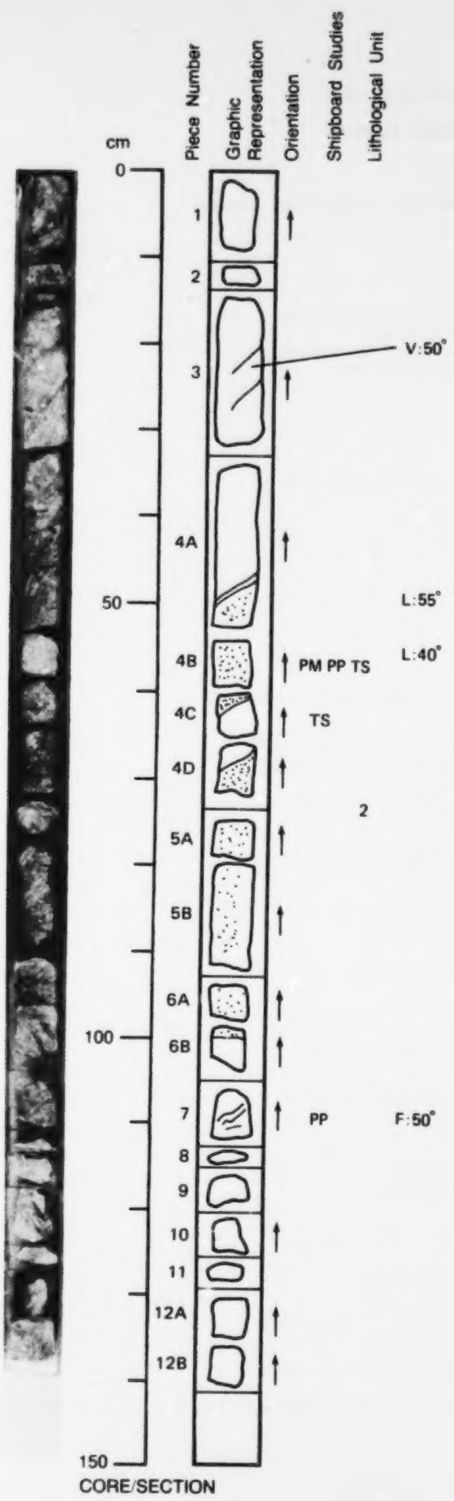
### Olivine-Bearing Gabbro (Weakly Foliated, Coarse-Grained)

### Pieces 11-16

**COLOR:** Pale to medium gray.
**LAYERING:** None.
**DEFORMATION:** Weak foliation defined by elongate pyroxenes dipping 42°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: 50% by secondary plagioclase.

Clinopyroxene—Mode: 48%.
Crystal size: Up to 2.5 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Elongate crystals.
Percent replacement: 10%.

Olivine—Mode: 2%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Green amphibole forms 5%-10% of the rock.
Percent vein material: 3%.
Vein material: White mineral filling horizontal veinlets. A few irregularly dipping veinlets.


cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1
2
3
4A
4B
4C
4D
5A
5B
6A
6B
7
8
9
10
11
12A
12B
V:50°
L:55°
L:40°
PM PP TS
TS
2
PP
F:50°
CORE/SECTION

**118-735B-13R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-12B**

### Olivine Gabbro

**Pieces 1 and 2**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Almost none.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 15 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-45%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 15%-20% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 3-18 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >50% by amphibole and mica (phlogopite?) or talc(?) and opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: 10%-15%
Texture: Amphibole replacing clinopyroxene. Trace of pyrite.
Percent vein material: None (not observed).
Vein material: None.

### Gabbro

**Pieces 3-6B, and 10-12B**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Almost none.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 15%-20% by amphibole.

Olivine—Mode: <5%.
Crystal size: None.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >50% by tremolite and mica and opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replacing clinopyroxene.
Percent vein material: None.
Vein material: None.

## 118-735B-13R-2 (continued)

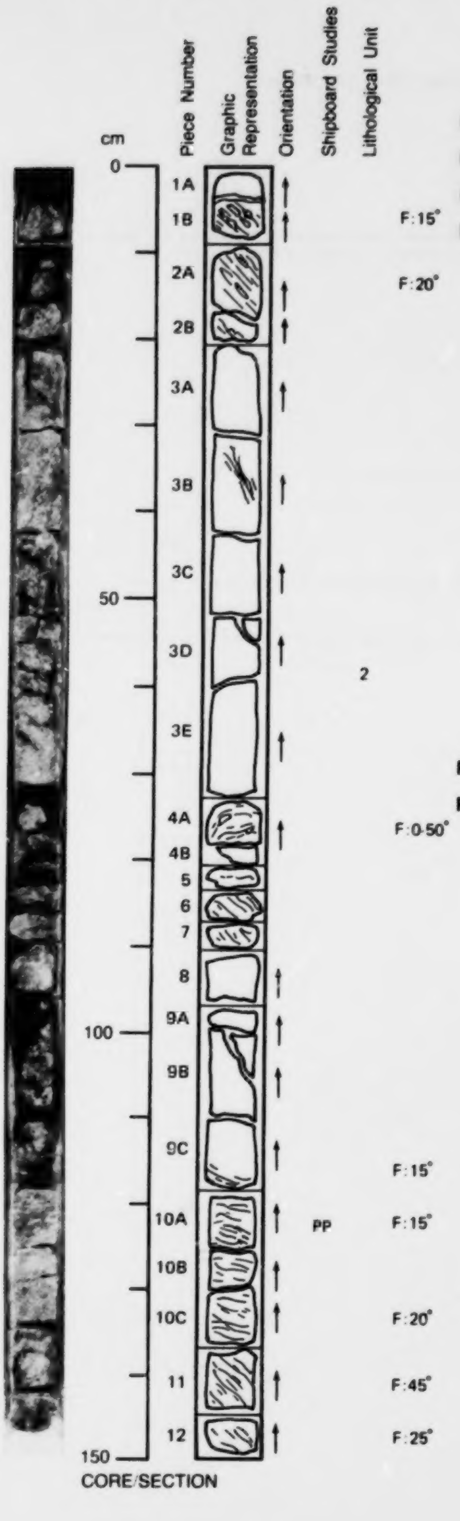
### Porphyroclastic Metagabbro

### Pieces 7-9

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by stretched plagioclase and clinopyroxene, and bands of recrystallized plagioclase and pyroxene. Inclination of foliation 15°-25°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 58%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Trace, prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >10% by amphibole.

Olivine—Mode: Trace to 2%
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensively by tremolite and mica and opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: >10%.
Texture: Amphibole replacing clinopyroxene. Trace prehnite replacing plagioclase.
Percent vein material: None.
Vein material: None.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1A
1B
2A
2B
3A
3B
3C
3D
3E
4A
4B
5
6
7
8
9A
9B
9C
10A
10B
10C
11
12
F:15°
F:20°
F:0-50°
F:15°
PP
F:15°
F:20°
F:45°
F:25°
2

**118-735B-13R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-12**

### Gabbro

**Pieces 1A, 2B-3E**

**COLOR:** Gray.
**LAYERING:** Piece 3E: Plagioclase-rich layers (0.8-1.2 cm thick).
**DEFORMATION:** Almost none.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 15%-20% by amphibole.

Olivine—Mode: <5%.
Crystal size: None.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >50% by tremolite and mica and opaque mineral
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replacing clinopyroxene.
Percent vein material: None.
Vein material: None.

### Porphyroclastic Metagabbro

**Pieces 1B, 2A, 4A-7, and 9C (bottom)-12**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by stretched plagioclase and clinopyroxene, and bands of recrystallized plagioclase and pyroxene. Inclination of foliation 15°-25°.
Pieces 1B-2A: Have mylonitic bands.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 58%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Trace, prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >10% by amphibole.

Olivine—Mode: Trace to 2%
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensively by tremolite and mica and opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: >10%.
Texture: Amphibole replacing clinopyroxene. Trace prehnite replacing plagioclase.
Percent vein material: None.
Vein material: None.

## 118-735B-13R-3 (continued)

**Olivine Gabbro**

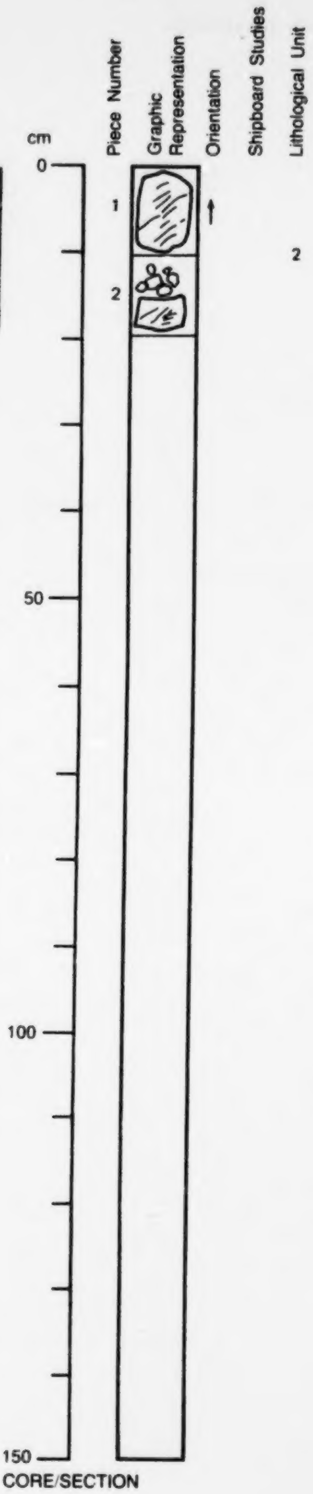
**Pieces 8-9C (115 cm)**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Almost none.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 50%.
  Crystal size: Up to 15 mm.
  Crystal shape: Subhedral-euhedral.
  Preferred orientation: None.
  Percent replacement: Not determined.

- Clinopyroxene—Mode: 35%-45%.
  Crystal size: Up to 20 mm.
  Crystal shape: Subhedral.
  Preferred orientation: None.
  Percent replacement: 15%-20% by amphibole.

- Olivine—Mode: 5%-15%.
  Crystal size: 3-18 mm.
  Crystal shape: Anhedral.
  Preferred orientation: None.
  Percent replacement: >50% by amphibole and mica (phlogopite?) or talc(?) and opaque mineral.

**SECONDARY MINERALOGY:**
- Total percent: 10%-15%
- Texture: Amphibole replacing clinopyroxene. Trace of pyrite.
- Percent vein material: None (not observed).
- Vein material: None.



**118-735B-13R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1 and 2

### Poorly Foliated Olivine Gabbro

### Piece 1

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by pyroxene and plagioclase porphyroclasts. Inclination of foliation varies between 15° and 45°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Weak.
Percent replacement: Trace of prehnite.

Clinopyroxene—Mode: 32%.
Crystal size: 3-28 mm.
Crystal shape: Subhedral.
Preferred orientation: Weak.
Percent replacement: >10% by amphibole.

Olivine—Mode: 8%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderately oxidized and replaced by serpentine(?).
**SECONDARY MINERALOGY:**
Total percent: >15%.
Texture: Amphibole replaces clinopyroxene. Olivine is slightly oxidized and replaced by serpentine (?). Limited replacement of plagioclase by prehnite.
Percent vein material: Not determined.
Vein material: Not determined.

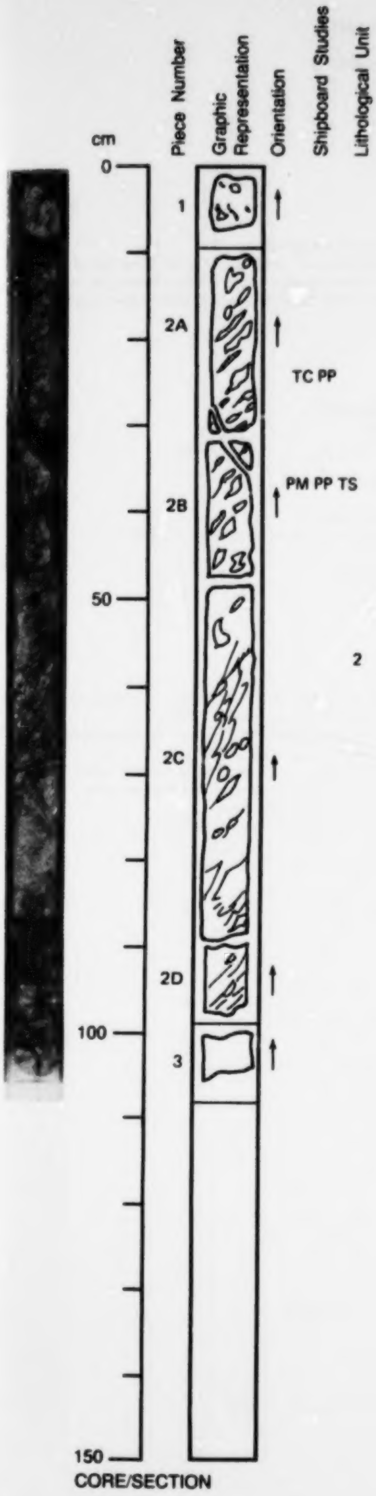
### Porphyroclastic Metagabbro

### Piece 2

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by stretched plagioclase and clinopyroxene, and bands of recrystallized plagioclase and pyroxene. Inclination of foliation 15°-25°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 58%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Trace, prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >10% by amphibole.

Olivine—Mode: Trace to 2%
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensively by tremolite and mica and opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: >10%.
Texture: Amphibole replacing clinopyroxene. Trace prehnite replacing plagioclase.
Percent vein material: None.
Vein material: None.



## 118-735B-14R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-3

## Augen Gneiss to Mylonitic Augen Gneiss Gabbro

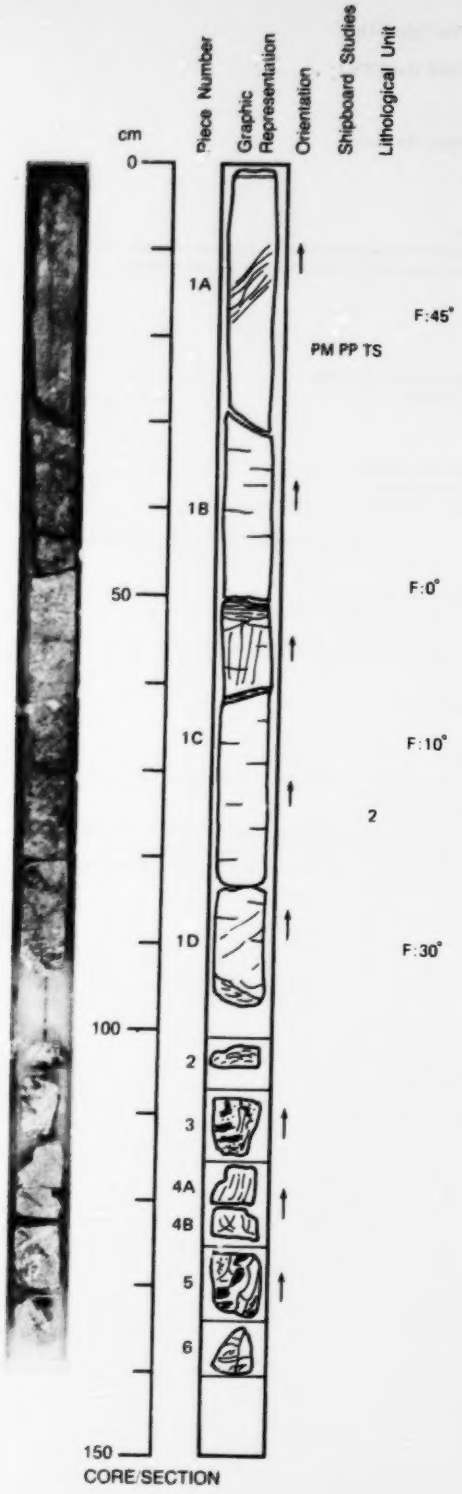
### Pieces 1-3

**COLOR:** Dark gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Coarse- to medium-grained clinopyroxene augen, 2 to 50 mm in a matrix of stretched recrystallized clinopyroxene and plagioclase defining a well-developed foliation.
Piece 2D: Locally mylonitic.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 0.4-1.6 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: trace by chlorite.

Clinopyroxene—Mode: 35%.
Crystal size: 0.8-5 cm.
Crystal shape: Anhedral, rounded or elongate.
Preferred orientation: In plane of foliation.
Percent replacement: 70% green amphibole rims pyroxene.

Olivine—Mode: <1% as 1.5 × 3.0 cm patch at approximately 51 cm. Recrystallized.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Elongate parallel to foliation.
Percent replacement: 100% by talc + tremolite + anthophyllite.

Iron-titanium oxides—Mode: Locally abundant (5%) at 61-68 cm.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred Orientation: Not determined.
Percent replacement: 0%.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Green amphibole locally rims pyroxene and occurs as lenses along foliation in addition to filling late crosscutting fractures.
Percent vein material: Up to 25% of rock.
Vein material: Green amphibole. White veins (sodic plagioclase?) 0.1-0.5 mm cut the foliation subhorizontally in four or five places. Piece 2C (53-64 cm): Contains a zone rich in crosscutting, 0.5- to 2-mm-thick amphibole veins dipping steeply subparallel to foliation. Contains a trace of sulfides and phlogopite.



**118-735B-14R-2**

## UNIT 1 : OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-6**

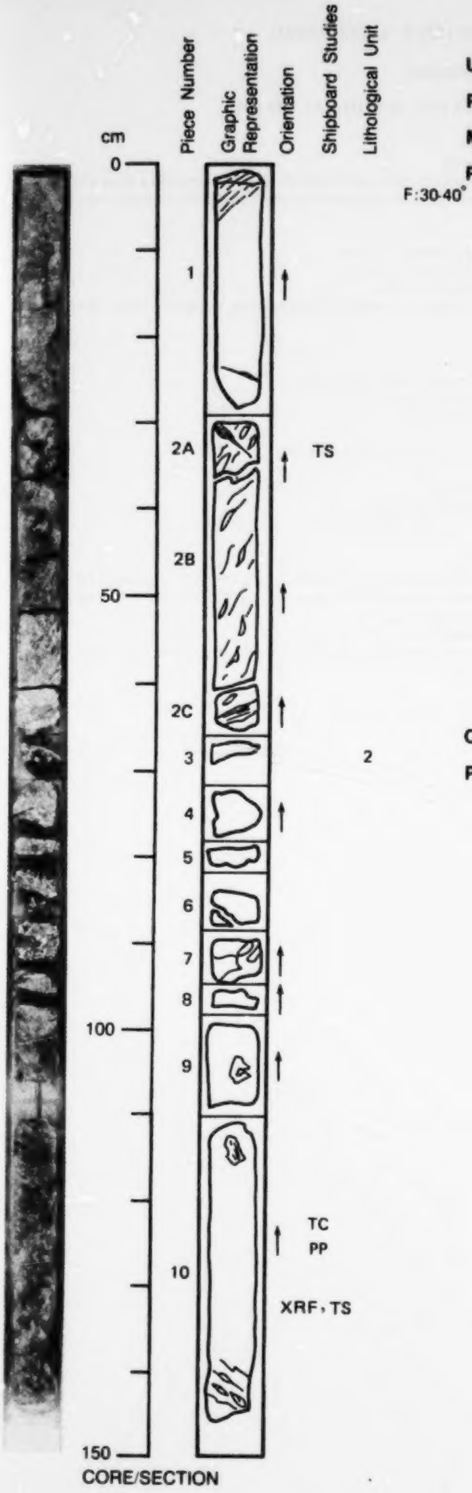
**Foliated Metagabbro**

**Pieces 1A-6**

**COLOR:** Varies from dark gray to white.
**LAYERING:** No obvious primary layering.
**DEFORMATION:** Defined by elongation of pyroxene and plagioclase.
Pieces 1A-1D: Dip varies from 45° at 14-28 cm, to 0° to 48-56 cm, to 10° at 63 cm, to 30° between 83-93 cm. Intervening areas are more massive, poorly foliated gabbro. More foliated areas are finer-grained, nearly mylonitic at 55 and 63 cm, but only well-foliated to augen gneissic elsewhere.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in foliation plane.
Percent replacement: Variable, 10%-100%.

Clinopyroxene—Mode: 40%.
Crystal size: 5-15 mm. Up to 3 cm in Piece 5.
Crystal shape: Anhedral.
Preferred orientation: Elongate in foliation plane.
Percent replacement: 2%-3% by amphibole to 100% by amphibole + albite.

Olivine—Mode: 0%-5% in first 5 cm of section.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 95%-100%.
**SECONDARY MINERALOGY:**
Total percent: 20%-100%.
Texture: 0-47 and 62-94 cm clinopyroxene is partially (2%-3%) replaced at rims by amphibole. Plagioclase is crosscut by veins filled by amphibole.
30-93 cm: Fractures <<1 mm are filled by white mineral (albite?) and nearly horizontal.
50-64 cm: Crosscut by amphibole-filled veins that are nearly vertical.
48-63 and 92-140 cm: Gabbro is strongly albitized and crosscut by amphibole veins. Foliation is no longer apparent, and gabbro is 70%-100% replaced by amphibole and albite.
Piece 5: Large crystals up to 3 cm have cores of clinopyroxene.
60 cm: Pistachio green mineral replacing plagioclase, probably epidote.
Percent vein material: 2%
Vein material: White mineral, probably albite or sodic plagioclase.



## 118-735B-14R-3

## UNIT 2 : OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-10

### Mylonitized Gabbro

### Pieces 1 (0-6 cm) and 2C (62-65 cm)

**COLOR:** Gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Pyroxene and plagioclase dipping in well-foliated layers at 30-40. Piece 2C (62-65 cm): 1-cm-thick band of fine-grained mylonite dipping at 20°, with sharp contacts with more steeply dipping foliated gneiss above.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 64%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement:

Clinopyroxene—Mode: 34%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement:

Olivine—Mode: 2%
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Replaced by talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Olivine replaced by talc.
Percent vein material: Not determined.
Vein material: Piece 1: Foliation crosscut by subhorizontal vein of albite or prehnite (1 mm).

### Olivine-Bearing Gabbro

### Pieces 1 (5-28 cm), 9, and 10 (101-104 cm)

**COLOR:** Dark gray.
**LAYERING:** No primary layering.
**DEFORMATION:** No apparent deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 64%.
Crystal size: 2-17 mm locally, generally 1-3 mm.
Crystal shape: Anhedral to subhedral granular.
Preferred orientation: None.
Percent replacement: >50%.

Clinopyroxene—Mode: 34%.
Crystal size: 2-17 mm.
Crystal shape: Anhedral to locally subhedral granular.
Preferred orientation: None evident.
Percent replacement: 30%.

Olivine—Mode: 2%, occurs locally.
Crystal size: 3 mm.
Crystal shape: Anhedral granular.
Preferred orientation: None.
Percent replacement: 100%.
**SECONDARY MINERALOGY:**
Total percent: 40%.
Texture: Amphibole common in 0.1- to 2-mm-thick crosscutting veins and rimming clinopyroxene (8%). Olivine locally pseudomorphed by talc except for olivine-rich zone at 25-29 cm, where it is also oxidized.
Percent vein material: 1%.
Vein material: Amphibole.
**COMMENTS:** Texture is anhedral granular, locally subhedral, granular, coarse-grained (2-17 mm) pyroxene and plagioclase. Pieces 9 and 10 (101-141 cm): Pegmatodial zone average grain size is 40 mm. Texture varies from subhedral granular to anhedral granular. Coarse-grained (101-122 cm) and pegmatoidal (122-141 cm).

### 118-735B-14R-3 (continued)

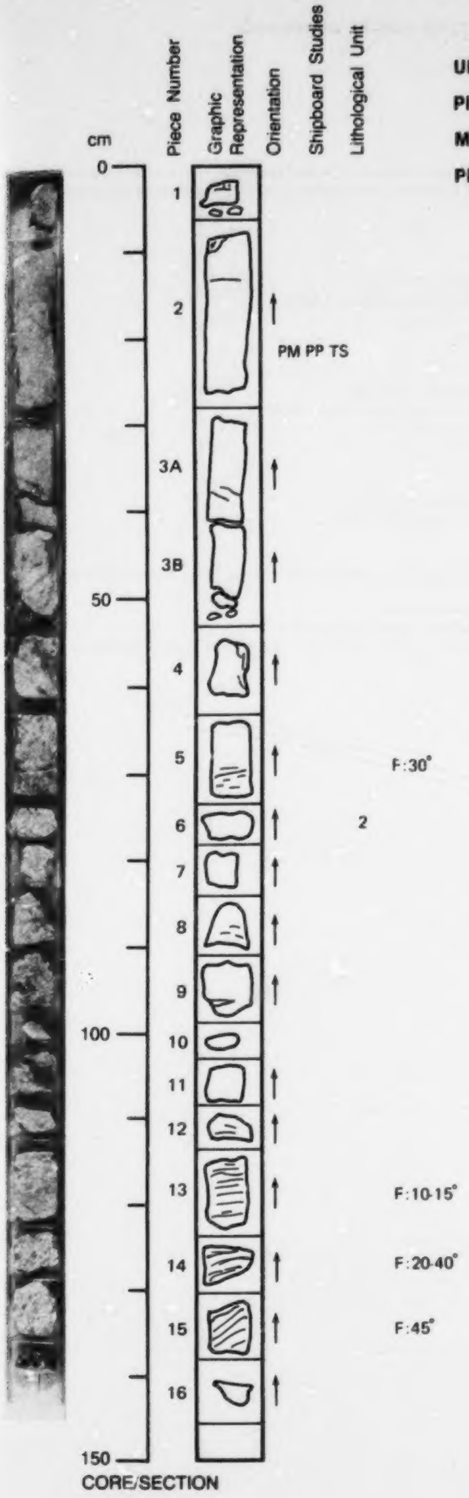
### Olivine-Bearing Metagabbro Augen Gneiss

### Pieces 2A-2C (29-62 cm), 2C-8 (65-101 cm), and 10 (141-148 cm)

**COLOR:** Dark greenish gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Well-developed gneissic foliation that becomes less well-developed toward base of this section, where some relict granular gabbroic texture is preserved. Foliation dips at 68°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 64%.
Crystal size: 2-17 mm locally, generally 1-3 mm.
Crystal shape: Anhedral to subhedral granular.
Preferred orientation: In plane of foliation.
Percent replacement: Not determined. Pieces 2C-8 (65-101 cm), feldspar is milky white.

Clinopyroxene—Mode: 34%.
Crystal size: 2-17 mm.
Crystal shape: Anhedral to locally subhedral granular.
Preferred orientation: In plane of foliation.
Percent replacement: Not determined.

Olivine—Mode: 1%. No olivine in Piece 10 (141-148 cm).
Crystal size: 3 mm.
Crystal shape: Anhedral granular.
Preferred orientation: In plane of foliation.
Percent replacement: 100% by rust-stained talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: 29-31 cm: Coarse olivine patch (6 × 15 mm) is partly (wholely ?) replaced by rust-stained talc. 29-40 cm: Extensive albitization in the vicinity of a 2- to 7-mm-thick vein of green amphibole. 55-58 cm: Greenish talc patches.
Percent vein material: Not determined.
Vein material: 2- to 7-mm-thick amphibole veins. Fracture system at 30-41 cm. Edges look like plagioclase replaced by epidote.



## 118-735B-14R-4

## UNIT 2 : OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-16**

### Massive to Poorly Foliated Gabbro

**Pieces 2-12**

**COLOR:** Gray with white to white-brown plagioclase, where altered.

**LAYERING:** None.

**DEFORMATION:** Pieces 5, 8, 9, and 12: Some weak foliation defined by elongation of plagioclase-rich zones. Plagioclase is probably cataclasized—some fracturing of pyroxene in some pieces.
Piece 4: Contains fracture at 62° with brown alterations zone around it. No offset.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-60%.
Crystal size: 0.2-1.0 cm.
Crystal shape: Anhedral.
Preferred orientation: Sometimes elongated in the foliation.
Percent replacement: Fresh to altered—brownish to greenish cast, epidote + clay minerals in the more deformed plagioclase between 53-109 cm.

Clinopyroxene—Mode: 40%-60%.
Crystal size: 3-35 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: Quite fresh, except near veins where there is some amphibole development.

Olivine—Mode: Variable, 0%-5%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral, interstitial.
Preferred orientation: None.
Percent replacement: All variously serpentinized. More deformed sections have clayey orange pseudomorphs. Percent replacement high at 36-40 cm.

**SECONDARY MINERALOGY:**

Total percent: <2% to 20% (high in lower half of interval).
Texture: Secondary phases are clay minerals, tremolite(?), serpentine after olivine, some plagioclase alteration giving a brownish cast.
Percent vein material: 1%-2%.
Vein material: White to brown filling, albite/prehnite(?), some clay minerals.

**COMMENTS:** Piece 2: There is a feldspathic vein on the upper corner with amphibole alteration on the margin—probably late stage, maybe deuteric. The igneous grain size changes dramatically from 2-3 mm to 2-3 cm in <1 cm—such transitions occur at 26, 32, and 36 cm. Pieces 3, 4, and 9 have clinopyroxene up to 3 cm long.

118-735B-14R-4 (continued)

**Gneissic Metagabbro**

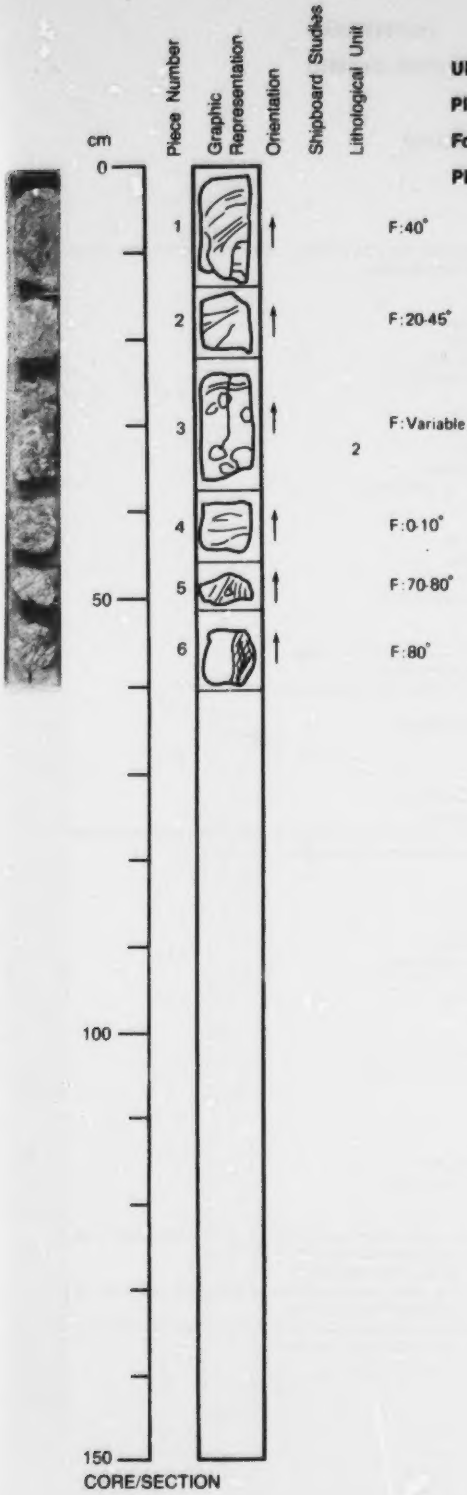
**Pieces 1, and 13-16**

**COLOR:** Green-white.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic, clinopyroxene and plagioclase augen with a foliation defined by lenses of plagioclase and amphibole and amphibole (after clinopyroxene) alignment.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%.
Crystal size: <1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Lensoid in foliation.
Percent replacement: 70% to plagioclase neoblasts.

Clinopyroxene—Mode: 50%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Flattened in foliation.
Percent replacement: 80% to amphibole, some neoblasts.

Olivine—Mode: 5%.
Crystal size: 3 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in foliation.
Percent replacement: 100% to calcite/hematite.
**SECONDARY MINERALOGY:**
Total percent: 40%.
Texture: Largely green amphibole after clinopyroxene—some hematite after olivene, calcite replacing olivine.
Percent vein material: Not determined.
Vein material: Minor amphibole veining in veins up to 1 cm wide.
**COMMENTS:** Piece 1 has a feldspathic veinlet on one side, along which there is amphibole and epidote development.

**118-735B-14R-5**


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5
6
2
F:40°
F:20-45°
F:Variable
F:0-10°
F:70-80°
F:80°
CORE/SECTION

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-6**

**Foliated Porphyroclastic Metagabbro**

**Pieces 1-6**

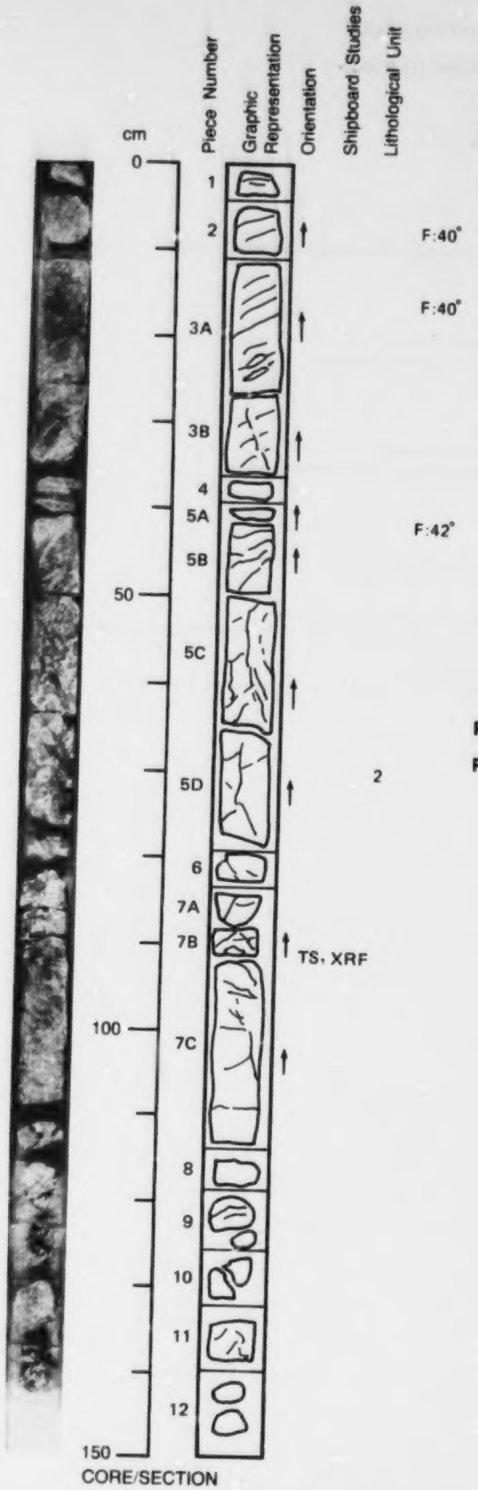
**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by stretching of plagioclase and clinopyroxene.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 45%.
Crystal size: <1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Lensoid in foliation.
Percent replacement: 70% to plagioclase neoblasts.

Clinopyroxene—Mode: 50%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Flattened in foliation.
Percent replacement: 80% to amphibole, some neoblasts.

Olivine—Mode: 5%.
Crystal size: 3 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in foliation.
Percent replacement: 100% to calcite/hematite.

**SECONDARY MINERALOGY:**
Total percent: 40%. Alteration more intense in Pieces 4-6.
Texture: Largely green amphibole after clinopyroxene. Some hematite after olivine. Calcite replacing olivine.
Percent vein material: Not determined.
Vein material: Minor amphibole veining. Pieces 1 and 3: Fracturing nearly vertical.



**118-735B-15R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-12

### Porphyroclastic Gabbro (Olivine-bearing)

### Pieces 1-3A (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Stretched clinopyroxene and plagioclase (+ olivine) define foliation. Foliation inclined about 40°. Clinopyroxene porphyroclasts.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 58%.
Crystal size: Not determined.
Crystal shape: Xenomorphic.
Preferred orientation: Stretched.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Not determined.
Crystal shape: Xenomorphic.
Preferred orientation: Stretched.
Percent replacement: 15% by amphibole.

Olivine—Mode: 2%.
Crystal size: Not determined.
Crystal shape: Xenomorphic.
Preferred orientation: Stretched.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Amphibole (<5%) replaces clinopyroxene.
Percent vein material: Not determined.
Vein material: Amphibole(?) veinlets running perpendicular to foliation.

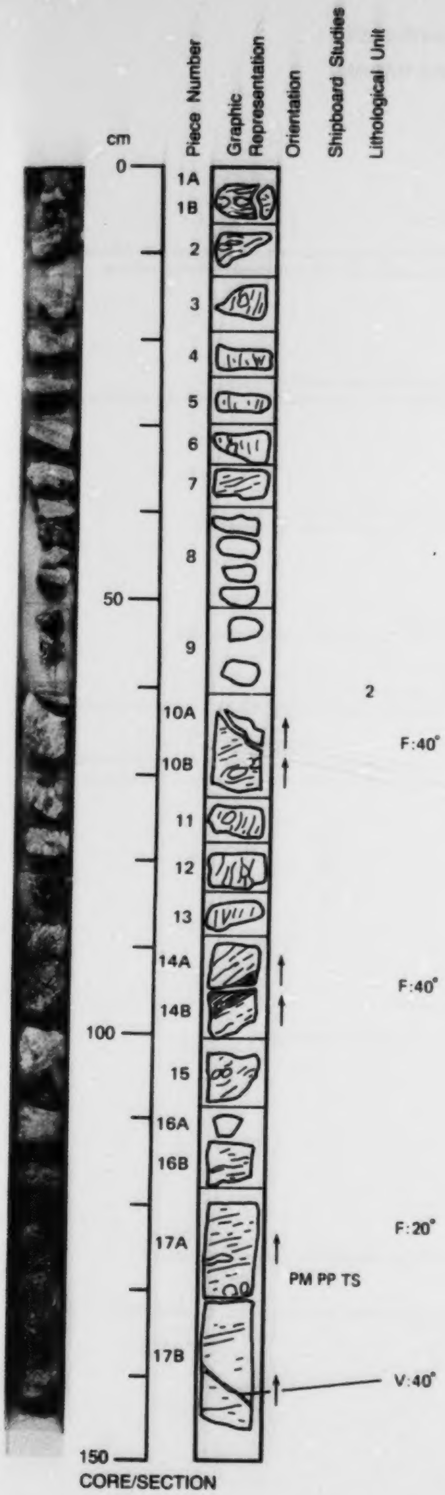
### Porphyroclastic Pegmatoidal Metagabbro

### Pieces 3A (bottom)-12

**COLOR:** Light gray to medium greenish gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Foliation defined by elongated clinopyroxene. Cataclastic deformation healed by amphibole veins that run vertical and perpendicular to the foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 5 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated.
Percent replacement: 15% by amphibole.

Olivine—Mode: 2%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Amphibole replaces clinopyroxene and occurs in veins. Albite and/or prehnite occuring in veins and partially replacing plagioclase.
Vein material: Amphibole, albite and/or prehnite.
**COMMENTS:** Sample has several 0.5-in.-wide, amphibole-filled veins running perpendicular to the foliation. Some horizontal amphibole-filled veinlets.
Pieces 3A and 3B: Clinopyroxene measures up to 5 cm long. Graditional boundary between Pieces 3A and 3B; Pieces 3A and 2B being finer-grained.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3
4
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8
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10A
10B
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14A
14B
15
16A
16B
17A
17B
2
F:40°
F:40°
F:20°
PM PP TS
V:40°
CORE/SECTION

## 118-735B-15R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-17B**

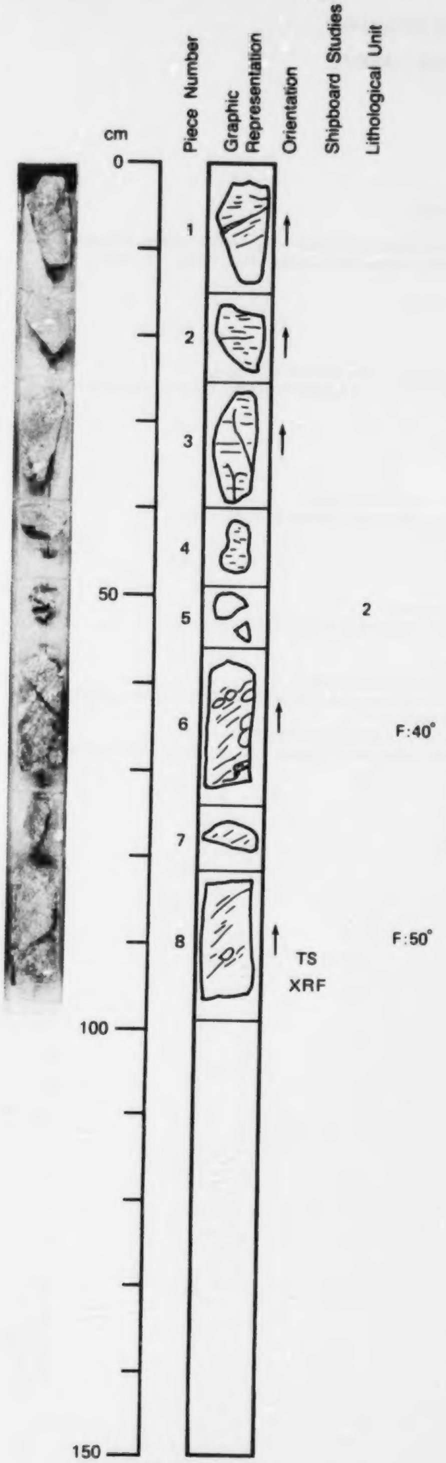
**Porphyroclastic Metagabbro**

**Pieces 1A-17B**

**COLOR:** Dark greenish gray with white bands.
**LAYERING:** None.
**DEFORMATION:** Foliation is defined by stretched plagioclase and pyroxene crystals. Foliation is also defined by amphibole-rich bands, probably after clinopyroxene. Foliation inclined approximately 40°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 10 mm.
Crystal shape: Anhedral.
Preferred orientation: Stretched and elongate parallel to foliation.
Percent replacement: Variously (moderate to extensive) replaced by sodic plagioclase and minor prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 15 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Extensive (>70%) replacement by amphibole.

Orthopyroxene—Mode: Trace.
Crystal size: <5mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Extensively replaced by tremolite and magnetite.
**SECONDARY MINERALOGY:**
Total percent: >70% (extensive).
Texture: Amphibole (>70%) replaces clinopyroxene.
Sodic plagioclase + prehnite(?) replaces approximately 20% of the original sample.
Percent vein material: Variable (<2%).
Vein material: Piece 17B: Amphibole vein approximately 5 mm thick.
**COMMENTS:** Pieces 1, 3, 10, 11, and 17A: Pegmatitic. Contains >1.0 cm clinopyroxene crystals.



**118-735B-15R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-8**

### Porphyroclastic Metagabbro

**Pieces 1-7**

**COLOR:** Dark greenish gray with white bands.
**LAYERING:** None.
**DEFORMATION:** Foliation is defined by stretched plagioclase and pyroxene crystals. Foliation is also defined by amphibole-rich bands, probably after clinopyroxene. Foliation inclined approximately 40°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 10 mm.
Crystal shape: Anhedral.
Preferred orientation: Stretched and elongate parallel to foliation.
Percent replacement: Variously (moderate to extensive) replaced by sodic plagioclase and minor prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 15 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Extensive (>70%) replacement by amphibole.

Orthopyroxene—Mode: Trace.
Crystal size: <5mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Extensively replaced by tremolite and magnetite.
**SECONDARY MINERALOGY:**
Total percent: >70% (extensive).
Texture: Amphibole (>70%) replaces clinopyroxene.
Sodic plagioclase + prehnite(?) replaces approximately 20% of the original sample.
Percent vein material: <2%.
Vein material: Pieces 1 and 3: Amphibole veins, 2-10 mm wide.
**NOTES:** Piece 6: Pegmatitic. Contains clinopyroxene porphyroclasts up to 1.5 cm. Also contains oxidized olivine near the bottom of the piece. Piece 4: Half of piece is fine-grained.

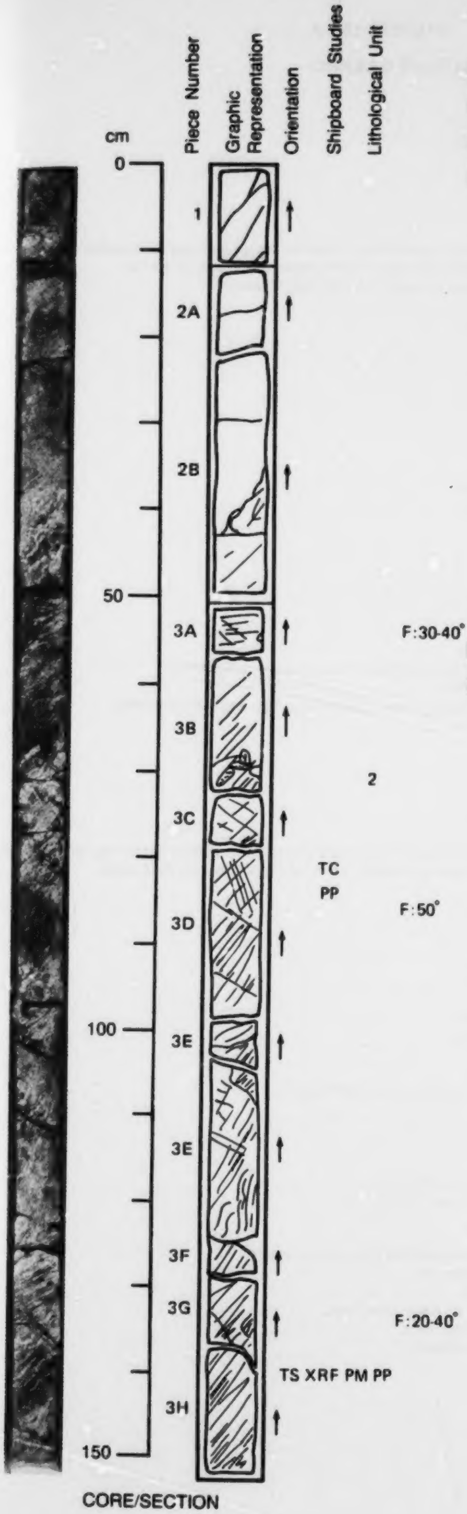
### Gabbro

**Piece 8**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Minor.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: Trace by sodic plagioclase and mica.

Clinopyroxene—Mode: 45%.
Crystal size: 2-6 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 10% by amphibole.

Olivine—Mode: 5%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Almost 90% by tremolite + mica or talc + opaque.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Green amphibole replacing clinopyroxene and filling late-stage veins.
Percent vein material: Trace.
Vein material: Amphibole.



**118-735B-16R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-3H

### Massive Metagabbro

### Pieces 1-2B (top)

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** Foliation very weak.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 35-40%.
Crystal size: <1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Lenses aligned in foliation.
Percent replacement: Not determined.

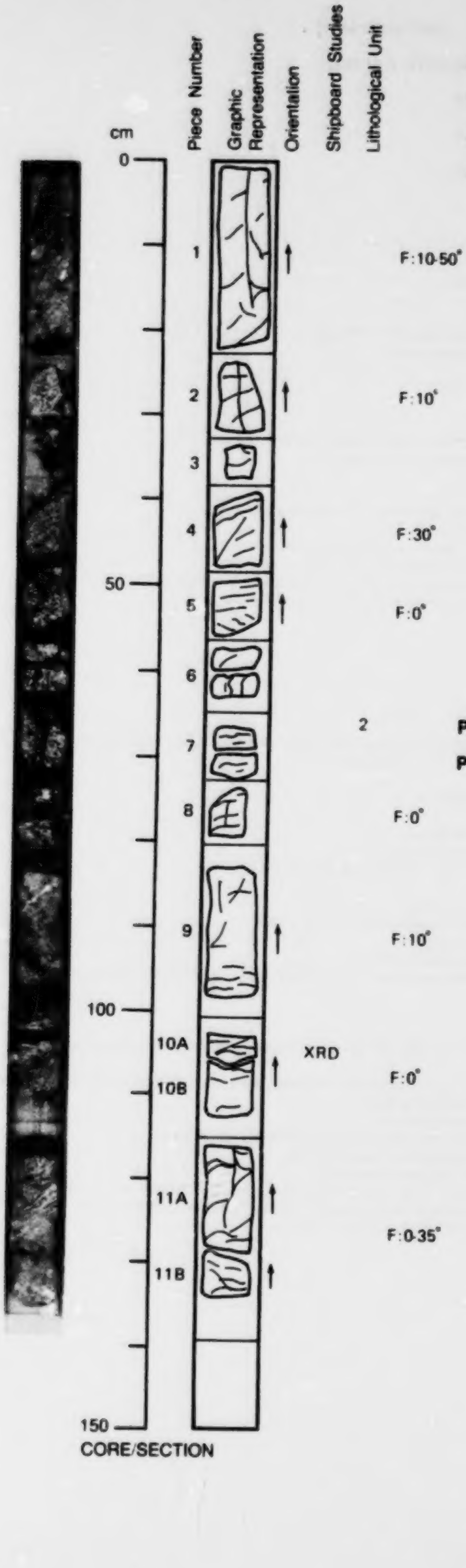
Clinopyroxene—Mode: 35-40%.
Crystal size: <1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Grains and clasts subparallel to foliation.
Percent replacement: Amphibole replacement.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Amphibole after clinopyroxene, some albitic plagioclase.
Percent vein material: Not determined.
Vein material: Very dark to black fracture filling amphibole.
**COMMENTS:** Piece 2A: Slightly more altered than Pieces 1 or 2B.
Piece 2B: Porpyroclastic texture at bottom and top of the piece.
Pieces 1 and 2A-2B: Albitized zones at 8-20 and 39-46 cm.

### Porphyroclastic Metagabbro

### Pieces 2B (bottom)-3H

**COLOR:** Dark gray to green gray.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic, moderate to well-developed foliation defined by amphibole alignment and porphyroclasts—gneissic in lower part.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: <1-5 mm.
Crystal shape: Anhedral, elongate.
Preferred orientation: Aligned foliation.
Percent replacement: Various, neoblasts of plagioclase.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1.5 cm porphyroclasts at 67 cm (bronze hue).
Crystal shape: Anhedral, elongate.
Preferred orientation: Elongate in foliation.
Percent replacement: Amphibole after clinopyroxene variously; freshest intervals at 62-64, 85-92, and 101-108 cm.
**SECONDARY MINERALOGY:**
Total percent: 10%-90%.
Texture: Greenish amphibole after clinopyroxene. White albitic plagioclase after calcic plagioclase.
Late-stage amphibole veins perpendicular to foliation. Also fractures perpendicular to foliation with a little offset and drag along them.
Percent vein materail: Not determined.
Vein material: Dark amphibole veins, almost perpendicular to foliation.
**COMMENTS:** 62-64, 85-92, and 101-108 cm—Fresh intervals.
Piece 3D: Dark layer with reduced albitization.
Pieces 3G-3H have a similar mineralogy but are more gneissic in texture with bands of plagioclase neoblasts and porphyroclasts alternating with bands of clinopyroxene porphyroclasts and amphibole after clinopyroxene.



**118-735B-16R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-11B

### Poorly Foliated Metagabbros

### Pieces 1, 4, 9, 11A, and 11B

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Pyroxene crystals are flattened into foliation planes that vary from weakly to well defined. Grain size variation 1 cm and in some places granulated to 2-3 mm.
Pieces 11A (top and middle), 9 (base), and 11B: Well-foliated.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 60%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Weak.
Percent replacement: 20%.

Plagioclase—Mode: 40%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Weak.
Percent replacement: 50%.

Opaques—Mode: Trace.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50%.
**SECONDARY MINERALOGY:**
Total percent: 50%.
Texture: Green hornblende pseudomorphs clinopyroxene, magnetite.
Percent vein material: 2%-3%.
Vein material: Late-stage veins cut the foliation at a high angle. Undeformed.

### Porphyroclastic Metagabbro

### Pieces 2, 3, 6A-7, 10A, and 10B

**COLOR:** Dark green to grayish white.
**LAYERING:** Not observed.
**DEFORMATION:** Flattening of plagioclase and pyroxene into foliation planes. Grain size varies from 3 mm to 2 cm. Piece 10A: Local thin bands, 3 mm, of plagioclase are developed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 3-20 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: 50%.

Clinopyroxene—Mode: 40%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: 20% replaced by amphibole.

Opaques—Mode: Trace.
Crystal size: <1 mm.
Crystal shape: Granular.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 30%-50%.
Texture: Green amphibole pseudomorphs clinopyroxene.
Iron hydroxides replace ilmenite.
Percent vein material: 5%.
Vein material: Veins filled by green amphibole.
Piece 7: Local veins filled by pyrite.
**COMMENTS:** Part of Piece 10A is gneissic.

## 118-735B-16R-2 (continued)

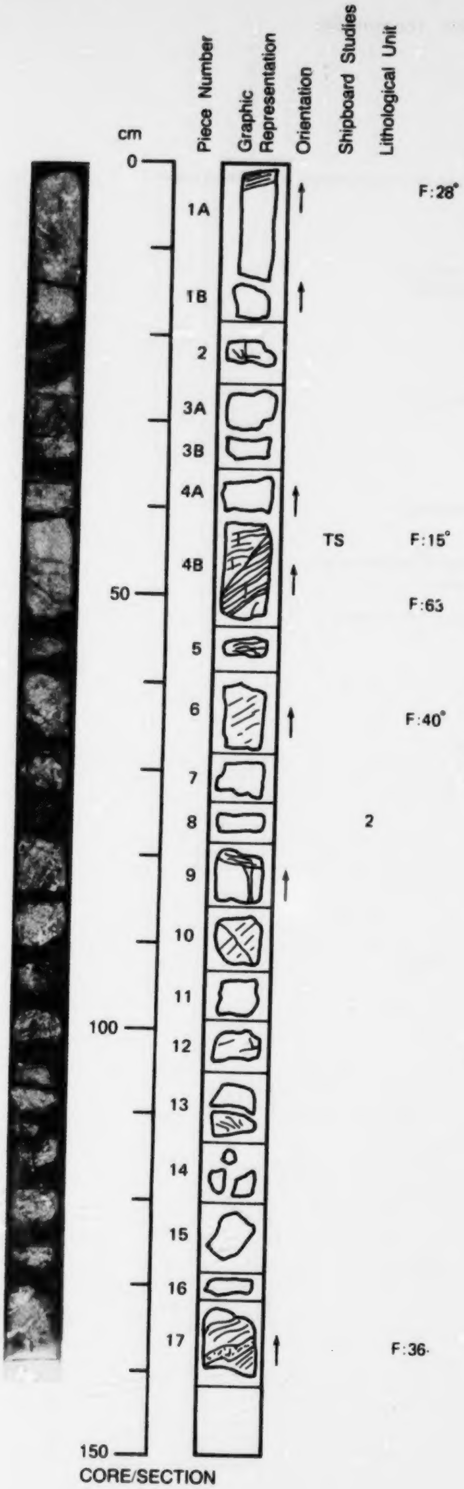
### Well-Foliated Metagabbro

### Pieces 5 and 8

**COLOR:** Dark green.
**LAYERING:** No.
**DEFORMATION:** Pyroxene and plagioclase are strongly aligned into foliation planes.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2-20 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%.
Crystal size: <2 cm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: Not determined.

Opaques—Mode: Trace.
Crystal size: <1 mm.
Crystal shape: Granular.
Preferred orientation: Yes.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 30-50%.
Texture: Green amphibole replaces clinopyroxene.
Iron hydroxides replace opaques.
Percent vein material: 3%.
Vein material: Amphibole veins cut the foliation plane at a high angle.



118-735B-16R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-17**

### Poorly Foliated Olivine-Bearing Metagabbro

**Pieces 1A and 1B**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Slight foliation. Elongation of pyroxene and plagioclase. Prominent foliation in top 3 cm. Moderate foliation in bottom.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: 2-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Weakly aligned in foliation.
Percent replacement: Replacement by albite.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-3 mm.
Crystal shape: Anhedral, elongate.
Preferred orientation: In foliation.
Percent replacement: Replacement by amphibole.

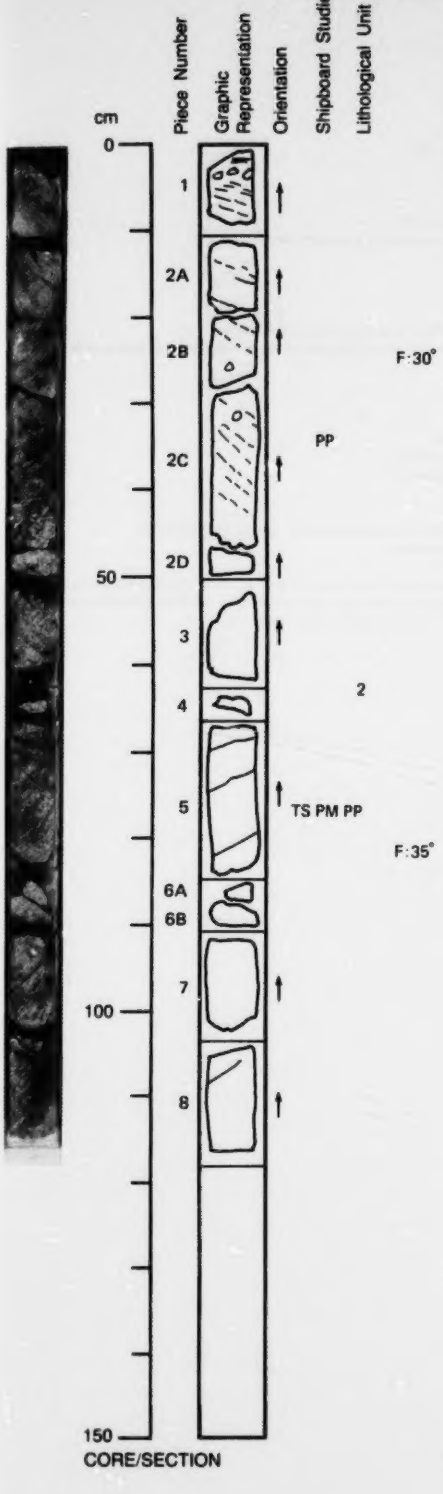
Olivine—Mode: 8%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 80%-100% replacement by talc, hematitic pseudomorphs.
**SECONDARY MINERALOGY:**
Total percent: 10% (central portion)—80% (upper end).
Texture: Amphibole replacing pyroxene and albitic plagioclase replacing plagioclase.
Percent vein material: Not determined.
Vein material: Not determined.

### Foliated to Poorly Foliated Amphibolitized Metagabbro

**Pieces 2-17**

**COLOR:** Grayish white to greenish gray.
**LAYERING:** None.
**DEFORMATION:** Slight to well-developed foliation, especially pronounced in Pieces 4B-6; foliation defined by aligned amphibole crystals.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Up to 30% relict, 40%-50% original.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in foliation.
Percent replacement: Extensive albitization—20%-30% total.

Clinopyroxene—Mode: up to 10% fresh—40%-50% original.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Aligned in foliation.
Percent replacement: Extensively amphibolitized.
**SECONDARY MINERALOGY:**
Total percent: In parts, almost 100%.
Texture: Green to green-black, massive to foliated amphibole replacing clinopyroxene—grains up 4 mm, anhedral. Piece 13: Minor altered olivine. 20%-30% white, anhedral albitic plagioclase fills a near-vertical vein in Piece 9.
Percent vein material: Not determined.
Vein material: Piece 4B: Yellowish epidote(?) in near-vertical late fractures.
Piece 7: 20%-30% anhedral (sometimes elongate) albitic plagioclase crystals fill vertical vein. 3% late veins, near-vertical, filled with chlorite, amphibole, and pyrite.
**COMMENTS:** Piece 4B: Has a 15° foliation in its least altered upper section cut by a steeply dipping amphibolitized zone with a strong 63° foliation.
Piece 16: Small mylonitic zone.
Piece 17: Most of piece is mylonitized with extensive amphibolitization—the upper corner includes a massive albite-amphibole metagabbro.
Pieces 9 and 10: Contain an aplite pod with a hornblende rich margin.



**118-735B-16R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-8**

### Mylonitized Metagabbro

**Pieces 1-C (0-40 cm)**

**COLOR:** Gray.
**LAYERING:** No igneous layering present.
**DEFORMATION:** Fine-grained foliated mylonite with occasional rolled augen of clinopryroxene 2-10 mm and coherent bands of stretched and recrystallized feldspar alternating with bands of green-gray recrystallized clinopyroxene and amphibole. Dips at 30° on average.
**PRIMARY MINERALOGY:**
Plagioclase—Mode 60%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: 20% by secondary plagioclase.

Clinopyroxene—Mode: 38%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: 55% by amphibole.

Olivine—Mode: 1%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: 100% by talc and clay minerals.

Iron-titanium-oxides—Mode: <1%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole along foliation and rimming clinopyroxene.
Olivine altered to talc + clay minerals.
Percent vein material: 0%.
Vein material: Not present.

### Olivine Gabbro

**Pieces 2C-3 (40-54 cm)**

**COLOR:** Gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Weakly shaped fabric locally developed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral granular.
Preferred orientation: Usually absent, weak elongation locally present.
Percent replacement: Not determined.

Clinopyroxene—Mode: 33%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral granular.
Preferred orientation: Usually absent, weak elongation locally present.
Percent replacement: Not determined.

Olivine—Mode: 2%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral granular.
Preferred orientation: Usually absent.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Amphibole rimming and replacing pyroxene.
Talc replacing olivine and occuring as pale green irregular vein in groundmass up to 2 mm thick. Piece 2D: Plagioclase locally stained orange and altered milky white.
Percent vein material: <1%.
Vein material: Talc or smectite.
**COMMENTS:** Gabbro/mylonite contact dips 32°.

118-735B-16R-4 (continued)

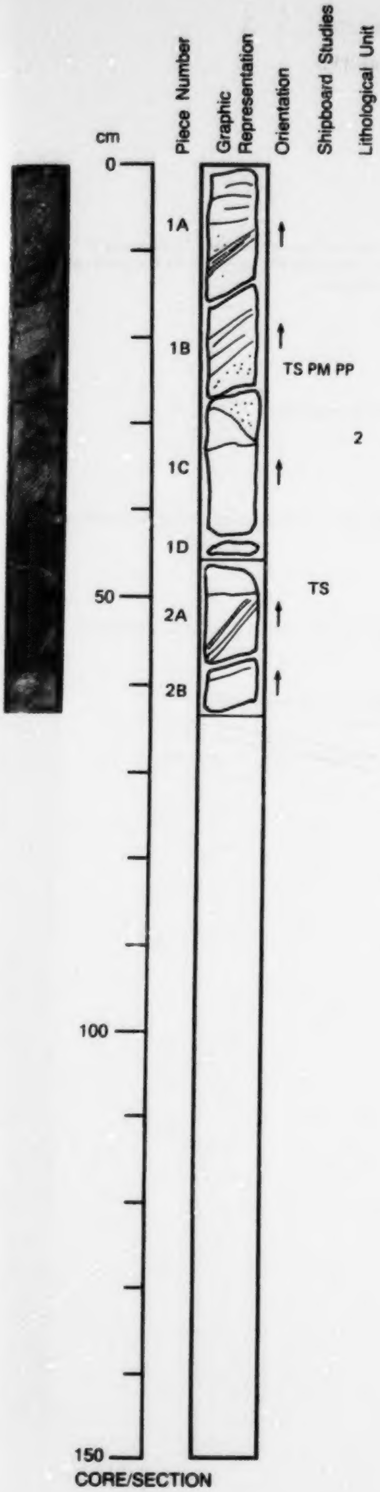
**Feebly Foliated Metagabbro**

**Pieces 3-6 (54-117 cm)**

**COLOR:** Gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Weak foliation dipping 35°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: Less than 4 mm
Crystal shape: Subhedral to euhedral.
Preferred orientation: Weak elongation in foliation plane.
Percent replacement: 0%.

Clinopyroxene—Mode: 36%.
Crystal size: Less than 8 mm.
Crystal shape: Interstitial anhedral forming oikocrysts locally.
Preferred orientation: None evident except for locally weak elongation in plane of foliation.
Percent replacement: 70%.

Olivine—Mode: 4%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole rimming and replacing pyroxene. Talc replacing olivine.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Individual grains of plagioclase and pyroxene show a weakly shaped anisotropy parallel to foliation with occasional zones of finer-grained mylonitic to gneissic (weak) material intervening. Clinopyroxene encloses euhedral plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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CORE/SECTION

**118-735B-16R-5**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-2B**

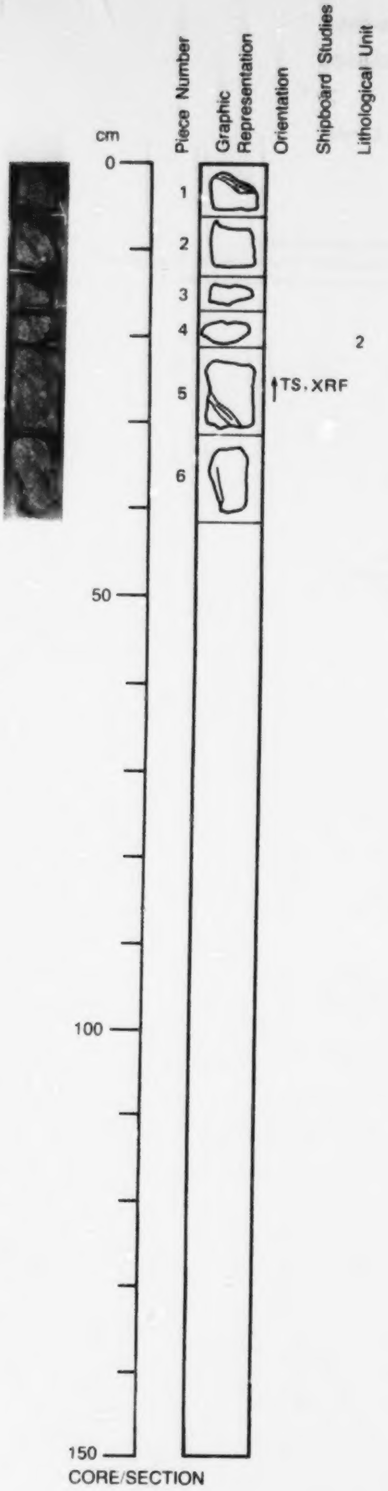
### Porphyroclastic Metagabbro with Mylonitic Bands

**Pieces 1A-2B**

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** Foliation weakly developed, especially in Piece 1C.
Pieces 1A, 1B, and 2A: Well-foliated metagabbro—porphyroclastic to mylonitic.
Lower part of Piece 1B and upper part of Piece 1C are finer-grained.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight.

Clinopyroxene—Mode: 45%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight.

**SECONDARY MINERALOGY:**
Percent replacement: Not determined.
Texture: Amphibole and albite replacement.
Percent vein material: Not determined.
Vein material: Not determined.


cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1
2
3
4
5
6
TS, XRF
2
CORE/SECTION

### 118-735B-17R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-6**

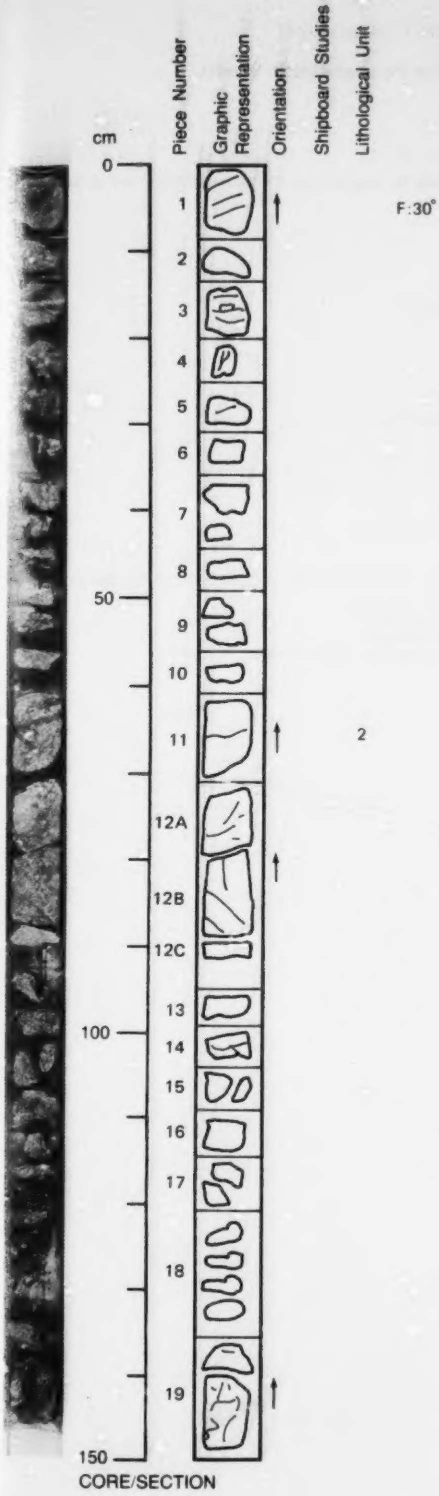
### Massive Olivine-Bearing Gabbro

**Pieces 1-6**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** 30°-60° from vertical, although not oriented—elongation of pyroxene and plagioclase—relatively little alteration to amphibole and albite. Looks like some cataclasis of plagioclase in places in more massive samples.
Pieces 1 and 5: 1-2 cm shear zones.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 50%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Some replacement by amphibole.

Plagioclase—Mode: 45%-50%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: A few with whitish bands or cores—fractures, perhaps albitized.

Olivine—Mode: 2%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Altered and veined by dark green assemblages—serpentine, amphibole(?).
**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: Talc + tremolite + chlorite after olivine in meshwork.
Dark green amphibole after clinopyroxene.
Percent vein material: <1%.
Vein material: Piece 6: Amphibole fills near vertical vein, <1 mm wide.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5
6
7
8
9
10
11
12A
12B
12C
13
14
15
16
17
18
19
F:30°
2
CORE/SECTION

### 118-735B-18R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-19

### Mylonitic Metagabbro

### Pieces 1 and 3

**COLOR:** Medium greenish gray.
**LAYERING:** None.
**DEFORMATION:** Piece 1: Strong mylonitic deformation (30°).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: Up to 4 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Porphyroclasts up to 1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole replacing clinopyroxene and occurring in veinlets in plagioclase-rich portions. Relatively high content of amphibole (up to 20%).
Percent vein material: Not determined.
Vein material: Amphibole.

### Porphyroclastic Metagabbro

### Pieces 2, 4, and 5

**COLOR:** Medium greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Foliation defined by plagioclase and amphibole stretching.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Precent replacement: Not determined.

Clinopyroxene—Mode: 50%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: Up to 100%.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Clinopyroxene almost completely replaced by amphibole.
Percent vein material: Not determined.
Vein material: Not determined.

## 118-735B-16R-1 (continued)

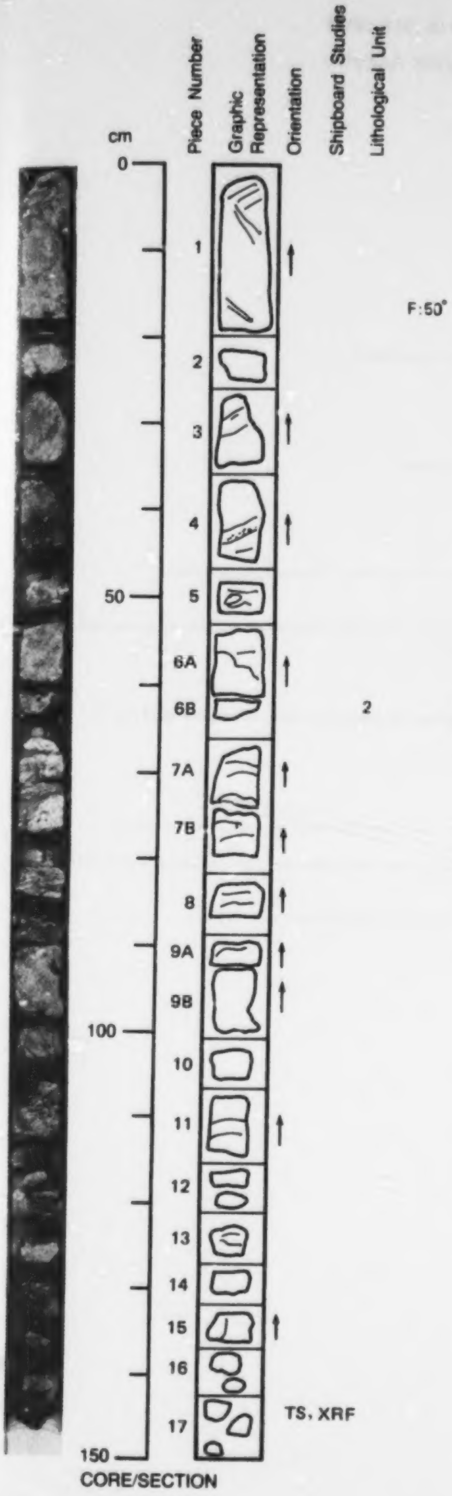
### Weakly Foliated Metagabbro (with Minor Porphyroclastic Bands)

**Pieces 6-19**

**COLOR:** Medium greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Foliation defined by stretched plagioclase and clinopyroxene (partially replaced by amphibole).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: 10% by amphibole.

Olivine—Mode: Trace.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: Completely replaced.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Clinopyroxene partially to almost completely replaced by amphibole (Pieces 17 through 19 most altered).
Olivine replaced by serpentine or chlorite(?).
Percent vein material: Veining ubiquitous.
Vein material: Amphibole, inclination about 40° on Pieces 1 through 3.



118-735B-18R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-17**

### Mylonitic to Porphyroclastic Metagabbro

**Pieces 4, 5, 6B, 8, 9A, and 10-13**

**COLOR:** Greenish gray to white.
**LAYERING:** No igneous layering.
**DEFORMATION:** Porphyroclasts of clinopyroxene (amphibolitized) and plagioclase. Foliation 10° to 40°. Pieces 4, 7, 8, and 11. Strongly mylonitized.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: Not determined.

Clinopyroxene—Mode: 60%-40%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Stretched.
Percent replacement: Up to 100%.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Clinopyroxene partially to almost completely replaced by amphibole. Plagioclase partially replaced by albite.
Percent vein material: Not determined.
Vein material: Minor amphibole veinlets inclining (60°-80°).
**COMMENTS:** Ratio of plagioclase to clinoproxene varies. Pieces 4 and 10: Fine-grained amphibolitic layers.

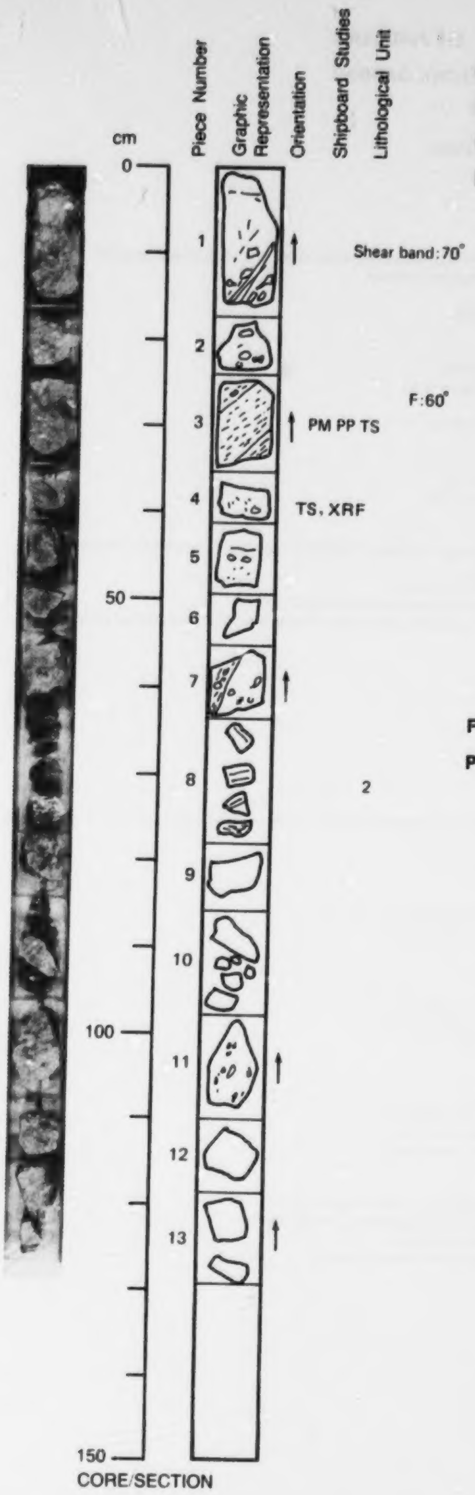
### Weakly Foliated Metagabbro

**Pieces 1-3, 6A, 9B, 14, and 17**

**COLOR:** Greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Shear bands in almost undeformed rock. Width of shear band, 0.5-1 cm, 5° inclination.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 2 cm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 43%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: < 10%.

Olivine—Mode: 2%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Clinopyroxene replaced by amphibole (< 10%).
Olivine partially serpentinized. Plagioclase partially albitized.
Percent vein material: Not determined.
Vein material: Some amphibole containing veins.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
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4
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7
8
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11
12
13
Shear band: 70°
F: 60°
PM PP TS
TS, XRF
2
CORE/SECTION

118-735B-18R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-13**

### Coarse-Grained Gabbro

**Pieces 1 and 2**

**COLOR:** Medium greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Shear bands at 70°.
**PRIMARY MINERALOGY:**
- Clinopyroxene—Mode: 50%.
  - Crystal size: Up to 5 cm.
  - Crystal shape: Anhedral.
  - Preferred orientation: None.
  - Percent replacement: 5%-10% by amphibole.
- Plagioclase—Mode: 48%.
  - Crystal size: Up to 2 cm.
  - Crystal shape: Subhedral.
  - Preferred orientation: None.
  - Percent replacement: Trace by albite(?).
- Olivine—Mode: 2%.
  - Crystal size: Up to 1 cm.
  - Crystal shape: Anhedral.
  - Preferred orientation: None.
  - Percent replacement: (Not measured) by iron oxides and clay minerals.

**SECONDARY MINERALOGY:**
- Total percent: <10%.
- Texture: Clinopyroxene replaced by amphibole. Plagioclase replaced by albite. Olivine replaced by iron oxides and clay minerals.
- Percent vein material: None.
- Vein material: None.

### Fine-Grained Amphibolite (Metamorphosed Microgabbro, Intrusive Body?)

**Pieces 3-6, and part of 7**

**COLOR:** Medium greenish gray.
**LAYERING:** None.
**DEFORMATION:** Pieces 3 and 7: Weakly foliated, boundaries inclined at 60° as shown.
**PRIMARY MINERALOGY:**
- Not to be determined confidently. Grain size generally <0.5 mm; partially up to 2 mm.

**SECONDARY MINERALOGY:**
- Total percent: >60%.
- Texture: Amphibole probably replacing clinopyroxene and olivine.
- Percent vein material: 0%.
- Vein material: None.

## 118-735B-18R-3 (continued)

### Porphyroclastic Metagabbro

### Piece 8

**COLOR:** Medium greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Porphyroclastic. Foliation is defined by stretched plagioclase and amphibole.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Trace by chlorite.

Clinopyroxene—Mode: 39%.
Crystal size: Up to 0.8 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Completely replaced by amphibole.

Olivine—Mode: 1%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Replaced extensively by iron oxides and clay minerals.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene almost completely replaced by amphibole.
Olivine replaced by iron oxides and clay minerals.
Percent vein material: None.
Vein material: None.

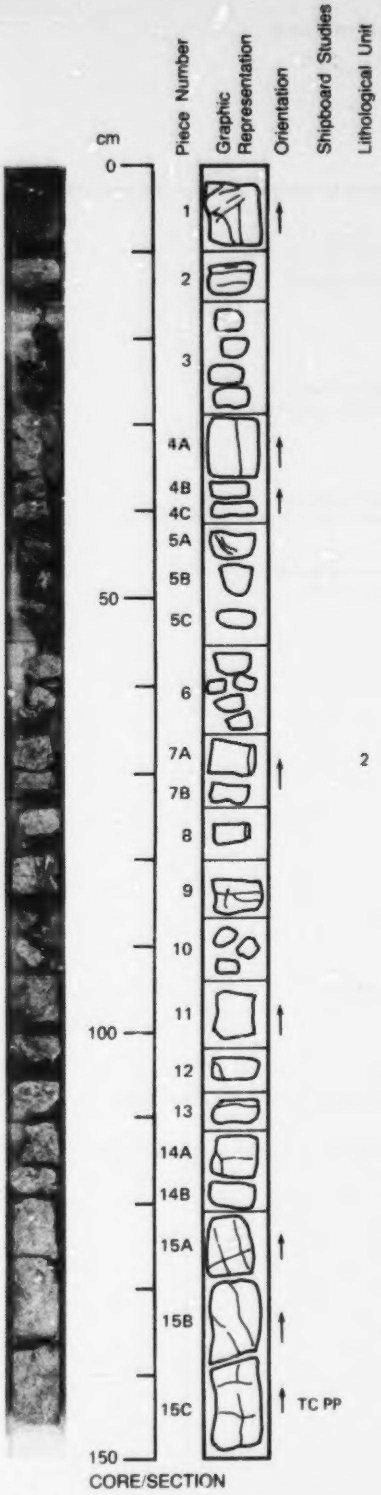
### Coarse-Grained Metagabbro

### Pieces 7 (part) and 9-13

**COLOR:** Medium gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Weak, partly feebly foliated.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 1.5 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Trace.

Clinopyroxene—Mode: 46%.
Crystal size: Up to 0.8 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%-15% by amphibole.

Olivine—Mode: Up to 4%.
Crystal size: Up to 0.8 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Replaced extensively by iron oxides and clay minerals.
**SECONDARY MINERALOGY:**
Total percent: <20%.
Texture: Amphibole (5%-15%), olivine replaced by iron oxides and clay minerals.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
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4A
4B
4C
5A
5B
5C
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7A
7B
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13
14A
14B
15A
15B
15C
2
TC PP
CORE/SECTION

**118-735B-19R-1**

**UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO**

**Pieces 1-15C**

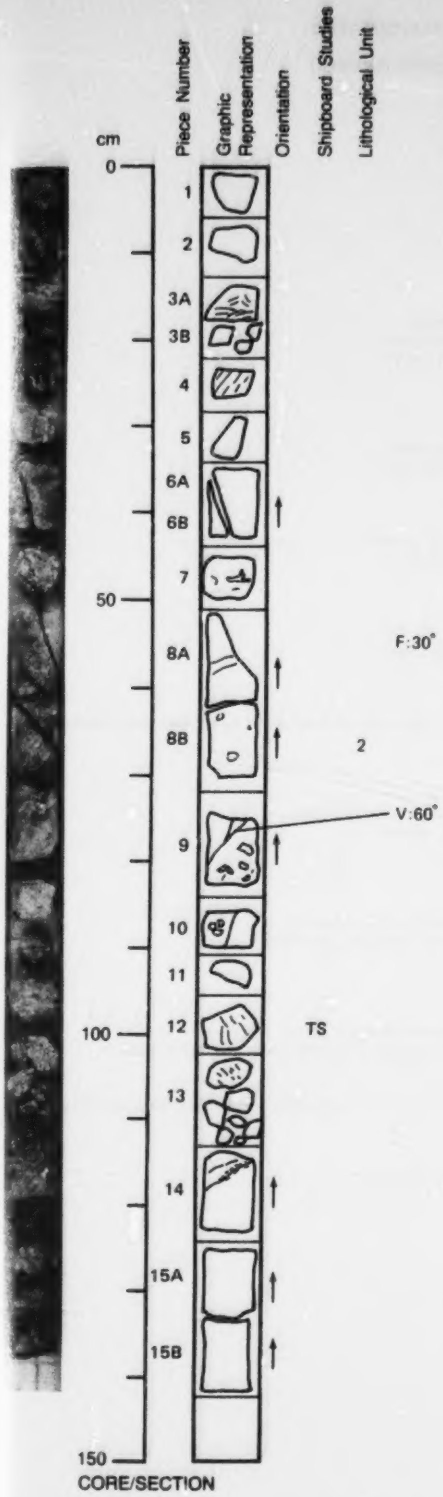
**Foliated to Porphyroclastic Metagabbro**

**Pieces 1-15C**

**COLOR:** White-greenish gray, with brownish pseudomorphs of olivine.
**LAYERING:** None.
**DEFORMATION:** Foliation, defined by stretched minerals. Piece 1 and 2 porphyroclastic.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-45%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliatio
Percent replacement: Partly replaced by amphibole.

Olivine—Mode: 2%-8%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Oxidized.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Moderate alteration. Olivine is oxidized, clinopyroxene is partly replaced by amphibole. Pieces 1 and 5A-5C show moderate low-temperature alteration, with clay minerals, iddigsite, epidote (?), and possibly prehnite.
Preferred orientation: Not determined.



**118-735B-19R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-15

### Weakly to Well-Foliated Metagabbro

### Pieces 1-13

**COLOR:** Greenish gray with yellowish green part.
**LAYERING:** No layering except for local concentration of olivine.
**DEFORMATION:** Weakly foliated. Foliation is defined by stretched plagioclase and pyroxene grains, and inclines 30°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Trace (mostly recrystalized into tiny grains).

Clinopyroxene—Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: 50%-90% by amphibole.

Olivine—Mode: 2%-7%.
Crystal size: 1.5 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: 100% oxidized and replaced by tremolite + mica + opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: 70%-90%.
Texture: Clinopyroxene is replaced by amphibole (amphibole 10%-15%). Olivine is oxidized.
Pieces 1-3A and 5-13: Low-temperature alteration zone.
Plagioclase is altered to sodic plagioclase. Olivine is altered into tremolite + mica + opaque mineral or is oxidized.
Percent vein material: Trace.
Vein material: Amphibole, 2-3 mm wide.
**NOTES:** Piece 7—Upper left is altered, but the lower right is relatively fresh and contains 1.5 cm olivine (7 vol%). The boundary is veined by amphibole.

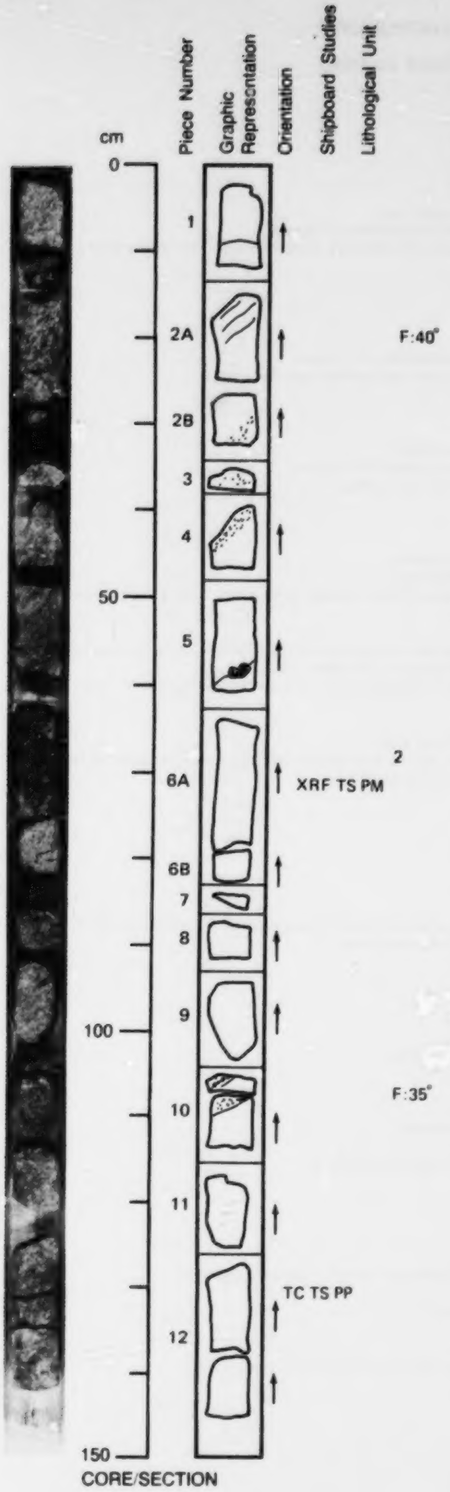
### Olivine-Bearing Gabbro

### Pieces 14 and 15

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Upper portion is very slightly foliated. No penetrative deformation except for near-vertical, very thin (<0.2 mm) amphibole veins.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral—anhedral.
Preferred orientation: None.
Percent replacement: Partly altered to amphibole.

Olivine—Mode: 3%.
Crystal size: Up to 5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: ?% to tremolite + mica + opaque aggregate.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Olivine is altered.
Percent vein material: Trace.
Vein material: <0.2 mm near vertical veins filled with amphibole.



**118-735B-19R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-12**

### Gabbro

**Piece 1**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-6 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 2-6 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: 10% amphibole replacing clinopyroxene and in veins.
Percent vein material: Not determined.
Vein material: Amphibole.

### Porphyroclastic Gabbro

**Pieces 2A-3, 5 (bottom), 10A, and 10B (top)**

**COLOR:** Medium greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Porphyroclastic. Foliation is defined by stretched plagioclase and amphibole.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Trace by chlorite.

Clinopyroxene—Mode: 39%.
Crystal size: Up to 0.8 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Completely replaced by amphibole.

Olivine—Mode: 1%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Replaced extensively by iron oxides and clay minerals.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene almost completely replaced by amphibole. Olivine replaced by iron oxides and clay minerals.
Percent vein material: None.
Vein material: None.
**COMMENTS:** Piece 5: Opaque-rich zone (ilmenite?).

118-735B-19R-3 (continued)

## Olivine-Bearing Gabbro

### Pieces 4-9

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-32 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 38%.
Crystal size: 3-20 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 25% by amphibole.

Olivine—Mode: 2%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 5% by talc, tremolite, and opaques.

**SECONDARY MINERALOGY:**
Total percent: 20%-30%.
Texture: Clinopyroxene altered to amphibole (25%). Olivine altered by talc + tremolite + opaques (5%).
Percent vein material: Not determined.
Vein material: Not determined.

## Olivine Gabbro

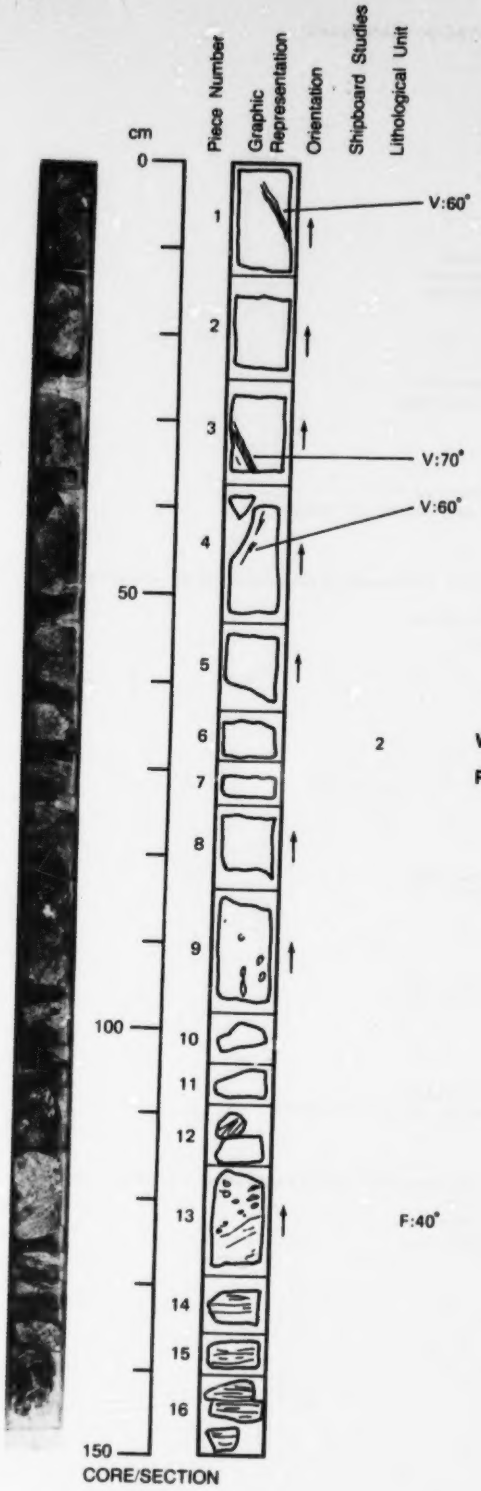
### Pieces 10B (bottom)-12

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-35%.
Crystal size: 2-12 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 15% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 5% by talc, tremolite, and opaques.

**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Clinopyroxene replaced by amphibole (15%). Olivine altered to talc + tremolite + opaques (5%).
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-19R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-16**

**Olivine Gabbro**

**Pieces 1-10**

**COLOR:** Gray, partly mottled with brown.
**LAYERING:** Not clear, but olivine concentrated (irregularly) locally.
**DEFORMATION:** Weak, slightly sheared along amphibole vein.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2.5 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: Trace.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 30% with amphibole.

Olivine—Mode: 5%-10%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 1% with tremolite + mica + opaque mineral.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Clinopyroxene is partly replaced by amphibole.
Olivine is replaced by tremolite + mica + opaque mineral from the margins.
Pieces 1, 3, and 4: Amphibole-rich shear zones.
Percent vein material: <3%.
Vein material: Amphibole.

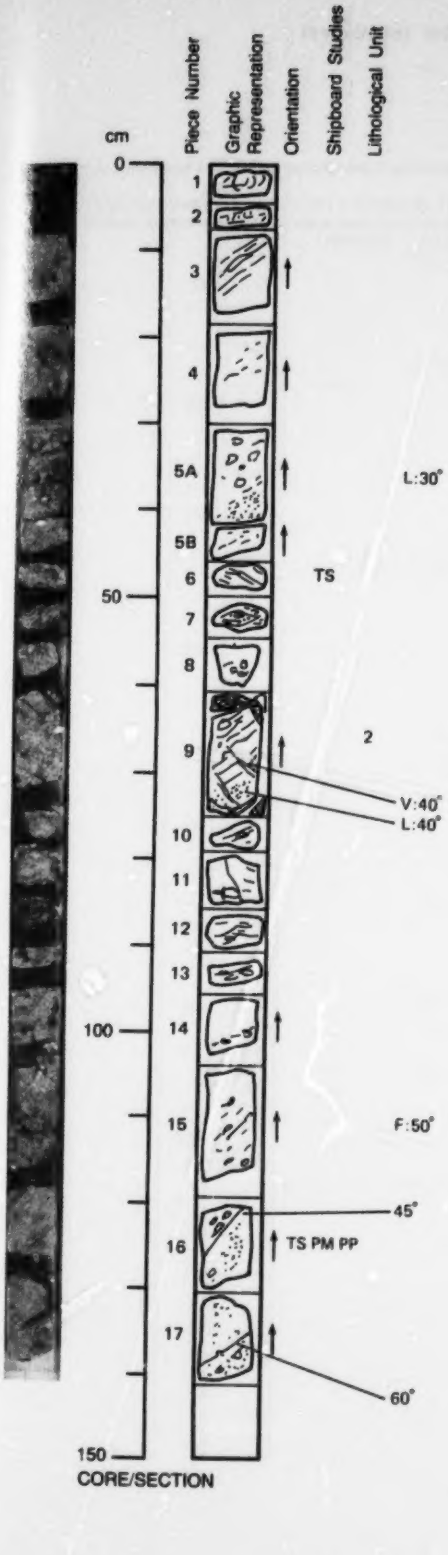
**Weakly to Well-Foliated Porphyroclastic Metagabbro**

**Pieces 11-16**

**COLOR:** Greenish gray.
**LAYERING:** None, except for oxide lenses.
**DEFORMATION:** Foliation is defined by stretched plagioclase and amphibole. Piece 12: Well foliated. Piece 13: Deformation weak. Piece 16: Mylonitic (one piece).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2.5 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Elongated in plane of foliation.
Percent replacement: Trace.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Elongated in plane of foliation.
Percent replacement: Strongly altered to amphibole.

Olivine—Mode: 5%-10% (7% in top of Piece 13).
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongated in plane of foliation.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: >20%-30%.
Texture: Clinopyroxene is intensely replaced by amphibole.
Grain size of amphibole is up to 1.5 cm. Magnetite-rich lenses parallel to foliation and in cracks.
Percent vein material: Not determined.
Vein material: Not determined.



**118-735B-19R-5**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-17**

### Porphyroclastic Metagabbro

**Pieces 1, 2, 6, and 7**

**COLOR:** Greenish gray, mottled by brown.
**LAYERING:** None.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to sodic plagioclase, epidote, and prehnite(?).

Clinopyroxene—Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 10% to 20% by amphibole. Oxidized.

Orthopyroxene—Mode: 5%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Oxidized.
**SECONDARY MINERALOGY:**
Total percent: >20%-30%.
Texture: Clinopyroxene is replaced by amphibole. Plagioclase is altered into albite and epidote and prehnite(?). Orthopyroxene is partly oxidized.
Percent vein material: 4%.
Vein material: Amphibole 1- to 7-mm-thick, inclining 30°-40°.
**COMMENTS:** Piece 1: opaque-rich part is present.

### Olivine Gabbro: Weakly Foliated Gabbro

**Pieces 3-5B, 8-16 (top), and 17 (bottom).**

**COLOR:** Greenish gray mottled by brown.
**LAYERING:** In pieces 5 and 9, the layer boundaries defined by difference in grain size are present. The boundary inclines 30°-40° almost parallel to the foliation (magmatic?).
**DEFORMATION:** Faint foliation. Foliation is defined by elongate olivine and pyroxene grains.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: Up to 1 cm.
Crystal shape: Subhedral.
Preferred orientation: Elongate parallel to layering.
Percent replacement: Not measured; by sodic plagioclase, epidote, and prehnite(?).

Clinopyroxene—Mode: 30%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Elongate parallel to layering.
Percent replacement: Up to 50% by amphibole.

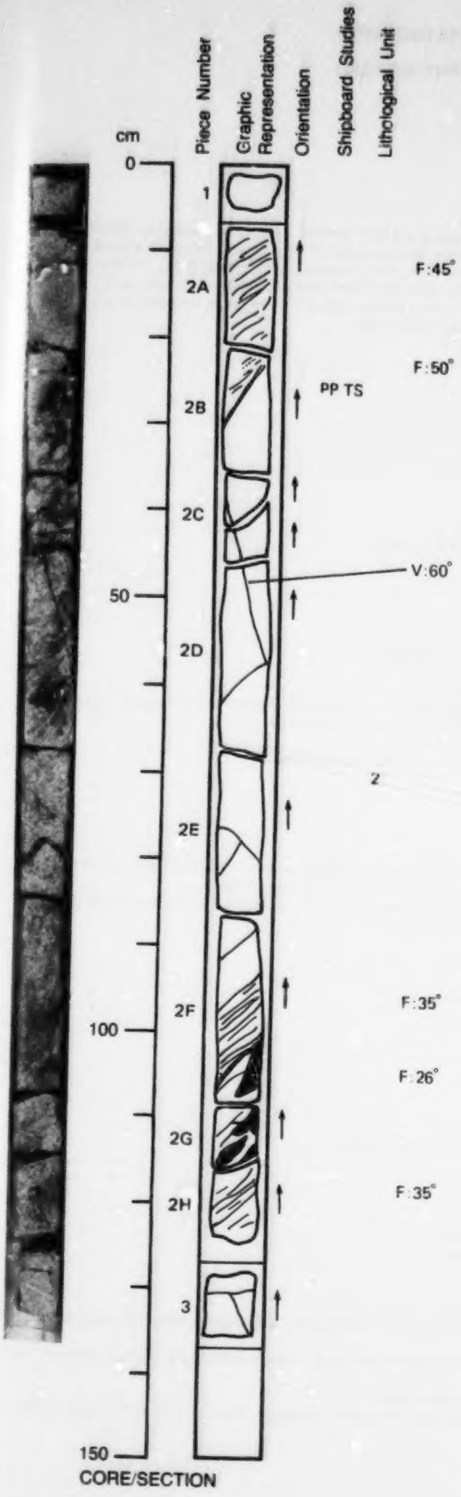
Orthopyroxene—Mode: 5%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Elongate parallel to layering.
Percent replacement: >40% oxidized.
**SECONDARY MINERALOGY:**
Total percent: Variable 10%-70%.
Texture: Clinopyroxene is replaced by amphibole especially in altered zone (40-90 cm).
Plagioclase is altered into albite and epidote and prehnite(?) in strongly altered part.
Orthopyroxene is partly oxidized.
Vein Material: Amphibole 1- to 7-mm-thick, inclining 30°-40°.
Percent vein material: 4%.

## 118-735B-19R-5 (continued)

### Metamorphosed Troctolite

### Pieces 16 (bottom) and 17 (top)

**COLOR:** Greenish gray.
**LAYERING:** None. Sharply cuts the surrounding coarse-grained gabbro. The boundaries incline 40-45
**DEFORMATION:** No clear foliation.
**PRIMARY MINERALOGY:** Aphyric. Olivine phenocryst. 4 mm, ophitic intergrowth with plagioclase. Replaced by talc + tremolite. Intergrown plagioclase (partially replaced by prehnite) and olivine (completely replaced by talc + tremolite).
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: See above.
Percent vein material: None.
Vein Material: None.



## 118-735B-20R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-3**

**Wehrlitic gabbro**

**Pieces 1-3**

**COLOR:** Dark Gray.

**LAYERING:** None well-defined. One olivine-rich zone at 100-120 cm; 2-4 cm elongate lenses, with interstitial plagioclase and clinopyroxene.

**DEFORMATION:** Weak foliation defined by elongate pyroxene and plagioclase grains in pieces 2A, 2B, 2F, 2G, and 2H. Olivine lenses elongate in foliation. Foliation dips 30°-35°. Some deformation concentrated at boundaries of olivine-rich lenses. Piece 2F contains an oxide-rich horizon just above the olivine-rich horizon.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50% (10%-15% in olivine-rich lenses).
Crystal size: Up to 5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

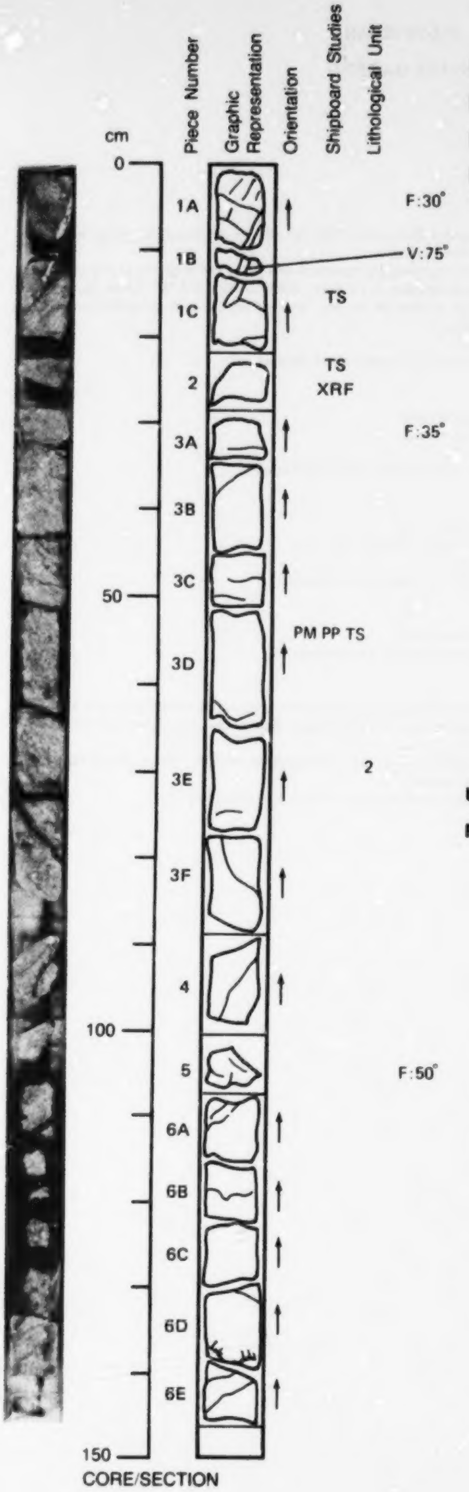
Clinopyroxene—Mode: 40% (50%-60% in olivine-rich lenses).
Crystal size: Up to 4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Some clayey alteration on rims.

Olivine—Mode: 10% (30%-35% in olivine-rich lenses)
Crystal size: Up to 3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Some alteration to serpentine/clay.

**SECONDARY MINERALOGY:**

Total percent: 10%.
Texture: Clay after clinopyroxene. Some albitization and granulation of plagioclase; Mylonitic zones (on olivine-lens boundaries) are amphibolitized. Some hematitic veined fractures.
Percent vein material: 3%.
Vein material: Some 2-mm-wide veins parallel to amphibole foliation. Mostly amphibole in veins, also some albite and epidote.

**COMMENTS:** Similar to olivine-rich zone in upper part of Core 118-735-20R-2.



**118-735B-20R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-6E

### Foliated Olivine-Rich Gabbro

### Pieces 1-3B (top)

**COLOR:** Yellow-green to dark green.
**LAYERING:** Present in Piece 3B, grain size and phase contact: 2-4 mm, olivine-rich vs. olivine-poor content is parallel to the foliation, dipping at 30°-35°, the whole olivine-rich gabbro layer is no totally recovered but is at least 20 cm thick. The contact is parallel to the foliation.
**DEFORMATION:** There is a clear foliation caused by flattening of olivine, plagioclase, and clinopyroxene grains. There is a fault plane in Piece 1C separating dark olivine gabbro and yellow-green olivine gabbro (coarser-grained).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Present.
Percent replacement: Slight.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Present.
Percent replacement: Slight to moderate.

Olivine—Mode: 10%-20%.
Crystal size: <4 mm.
Crystal shape: Anhedral.
Preferred orientation: Present.
Percent replacement: Slight to moderate.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Black amphibole replacing clinopyroxene. Iron hydroxide and clay replacing olivine.
Vein is filled by plagioclase (80%) and amphibole (20%).
Percent vein material: Not determined.
Vein material: Plagioclase (80%) and amphibole (20%).

### Undeformed Olivine-Poor Gabbro

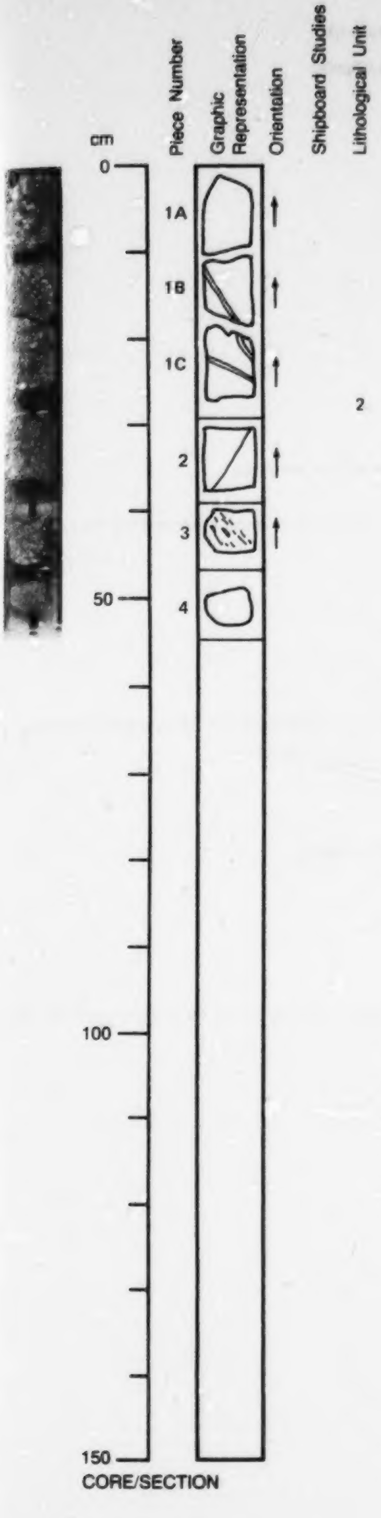
### Pieces 3B (bottom)-6E

**COLOR:** Greenish gray.
**LAYERING:** No layering except in Piece 6A where a contact between olivine-rich and olivine-poor gabbro (downhole) is observed. (See description of Pieces 1-3B.)
**DEFORMATION:** Very faint foliation seen in Pieces 5 and 6A, flattening of pyroxene and plagioclase. Otherwise, the gabbro is undeformed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-58%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral, recrystallized.
Preferred orientation: Variable.
Percent replacement: 50%.

Clinopyroxene—Mode: 40%.
Crystal size: 1-4 mm.
Crystal shape: Euhedral.
Preferred orientation: Variable.
Percent replacement: Moderate to complete.

Olivine—Mode: 2%-5%.
Crystal size: Not recorded.
Crystal shape: Anhedral.
Preferred orientation: Variable.
Percent replacement: Complete.

**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole replaces partially clinopyroxene, especially in deformed gabbros (Pieces 5 and 6A).
Veins filled by green amphibole in Pieces 3B-3E, 4, 6A, and 6D and along fault plane in Piece 1C.
Percent vein material: Not determined.
Vein material: Fractures are filled by chlorite, carbonate, iron hydroxides (Pieces 3F and 4).



**118-735B-20R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-4

### Gabbro

### Pieces 1A-3 (0-42 cm)

**COLOR:** Dark gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** None in hand specimen.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 7 mm average
Crystal shape: Anhedral granular.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 33%.
Crystal size: 7 mm average
Crystal shape: Anhedral granular.
Preferred orientation: None.
Percent replacement: Extensive amphibole alteration.

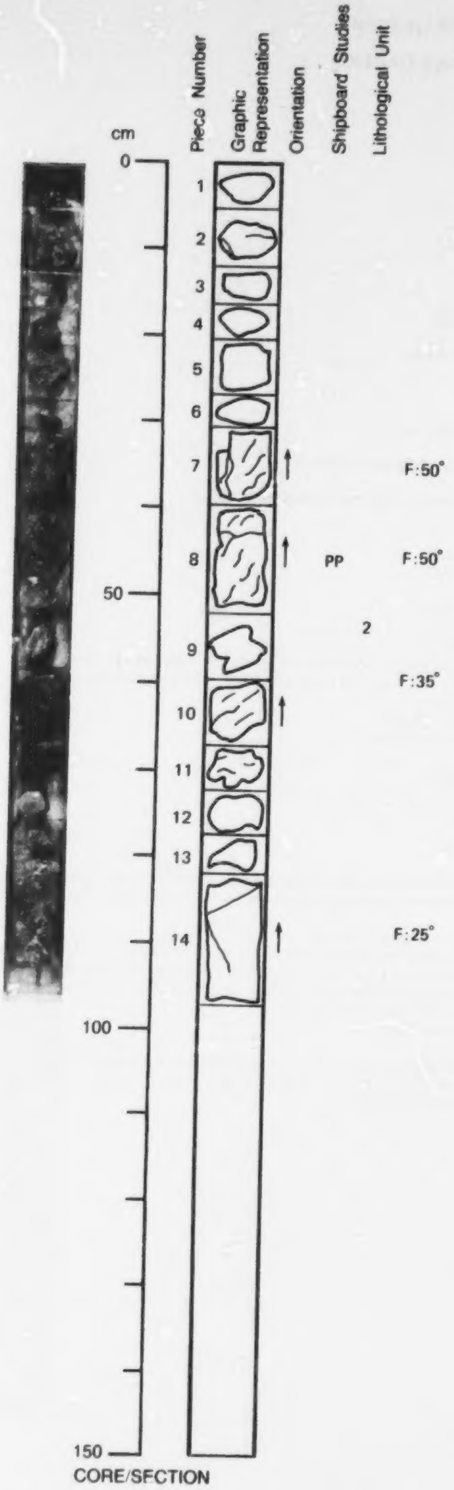
Olivine—Mode: (2%) badly altered and difficult to positively identify.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Nearly 100%.

Iron-titanium Oxides—Mode: Trace.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole is abundant, pseudomorphing and rimming primary clinopyroxene. It also occurs in several veins 0.1 to 1 mm thick. One vein, 4-mm-thick, contains a mixture of plagioclase and green amphibole.
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole.

### Gneissic and Mylonitized Metagabbro

### Pieces 3 (bottom) and 4 (42-54 cm)

**COLOR:** Gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Gneissic (41-445 cm) with plagioclase extensively recrystallized and elongated into schlieren defining the foliation. A few coarse pyroxene augen (0.5-1 cm) remain. Piece 4: Faint foliation.
**PRIMARY MINERALOGY:** Similar to olivine gabbro (above).
**SECONDARY MINERALOGY:** Clinopyroxene extensively pseudomorphed by amphibole. 1% iron-titanium oxides interstitial to plagioclase, pyroxene, and amphibole. Plagioclase vein 1-mm-thick along contact between gneiss and gabbro in Piece 3. Plagioclase-rich vein (contacts not sharply defined), 1-2 mm wide. Crosscuts foliation in Piece 4.
Percent vein material: Not determined.
Vein material: Plagioclase.
**COMMENTS:** Piece 4: Fine- to medium-grained rock with a very faint foliation. Mineralogy includes mostly plagioclase and amphibole, but the rock also contains 1% iron-sulfides (pyrite) and a few stringers of recrystallized clinopyroxene.



**118-735B-21R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-14**

**Gabbro**

**Pieces 1-6, and 13**

**COLOR:** Dark green.
**LAYERING:** Massive.
**DEFORMATION:** Undeformed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-7 mm.
Crystal shape: Anhedral.
Preferred orientation: No.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 1-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: By amphibole. Percent not determined.
**SECONDARY MINERALOGY:**
Total percent: 7%.
Texture: Amphibole replaces clinopyroxene and fills fractures. Iron-hydroxides and yellow-brown clay minerals.
Percent vein material: Not determined.
Vein material: Amphibole.

**Foliated Metagabbro**

**Pieces 7-12, and 14 (top)**

**COLOR:** Medium green to yellow green.
**LAYERING:** None.
**DEFORMATION:** Foliation plane defined by flattening of plagioclase and clinopyroxene. Grain size decreases from 5 to 2 mm.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 60%.
Crystal size: 2 mm.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: Largely replaced by amphibole.

Plagioclase—Mode: 40%.
Crystal size: 1-2 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Yes.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: About 40%.
Texture: Green amphiboles replacing clinopyroxene. Iron-hydroxides in fracture. Clay minerals in dissolution voids.
Percent vein material: Not determined.
Vein material: Iron-hydroxides.
**COMMENTS:** Piece 10: Porphyroclastic.

## 118-735B-21R-1 (continued)

**Foliated Ilmenite Gabbro/Poorly Foliated Olivine-Poor Gabbro**

**Piece 14 (bottom)**

**COLOR:** Greenish gray.
**LAYERING:** Contact between foliated ilmenite gabbro and olivine-poor gabbro. Foliation is parallel to the contact. Grain size is 2-3 mm and 2-10 mm, respectively. Contact is sharp and straight.
**DEFORMATION:** Foliation is marked by preferred orientation of pyroxene (1.5 cm long).
**PRIMARY MINERALOGY:**

Ilmenite gabbro: Plagioclase—Mode: 45%-50%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation. Yes.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: Not determined.

Ilmenite (magnetite)—Mode: 5%-10%, interstitial.
Crystal size: 1-4 mm.
Crystal shape: Granular.
Preferred orientation: Not seen.
Percent replacement: Not determined.

Olivine-poor gabbro: Plagioclase—Mode: 50%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: Not determined.

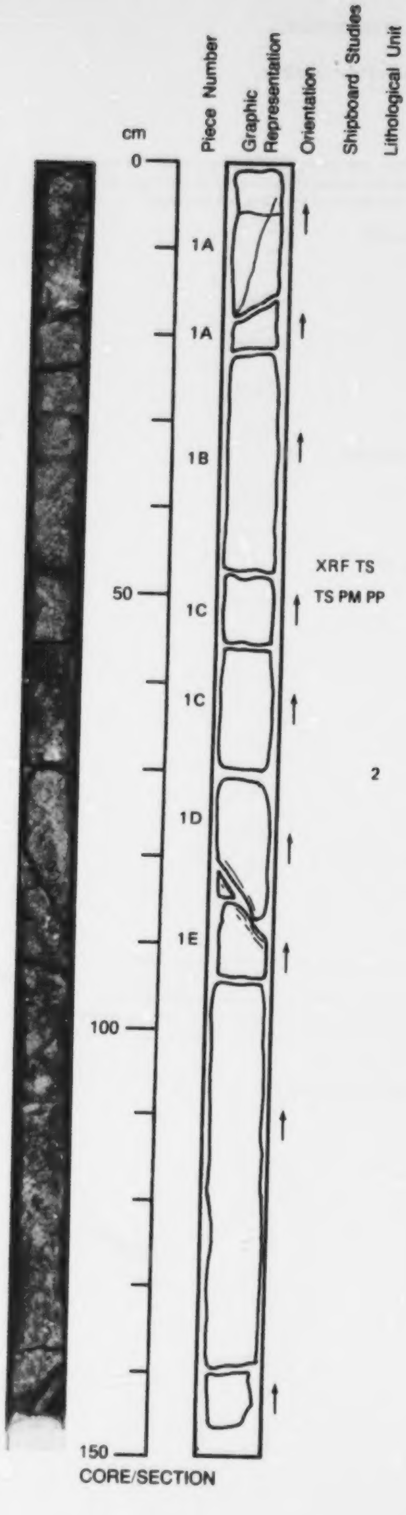
Clinopyroxene—Mode 45%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: Not determined.

Orthopyroxene—Mode: 3%.
Crystal size: 5 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: 30% oxidized, clay minerals.

Olivine—Mode: 2%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not seen.
Percent replacement: Almost total by magnetite, amphibole, and iron-hydroxide.

**SECONDARY MINERALOGY:**

Total percent: At least 45% in ilmenite gabbro; at least 50% in olivine-poor gabbro.
Texture: Hematite in plagioclase, green amphibole replaces pyroxene in ilmenite gabbro. Green to blue green amphibole replaces pyroxene, olivine replaced by magnetite, amphibole, and iron-hydroxide in olivine-poor gabbro.
Percent vein material: Not determined.
Vein material: 1- to 3-mm-thick, filled with green amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1A
1A
1B
XRF TS
50
1C
TS PM PP
1C
2
1D
1E
100
150
CORE/SECTION

**118-735B-21R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1G**

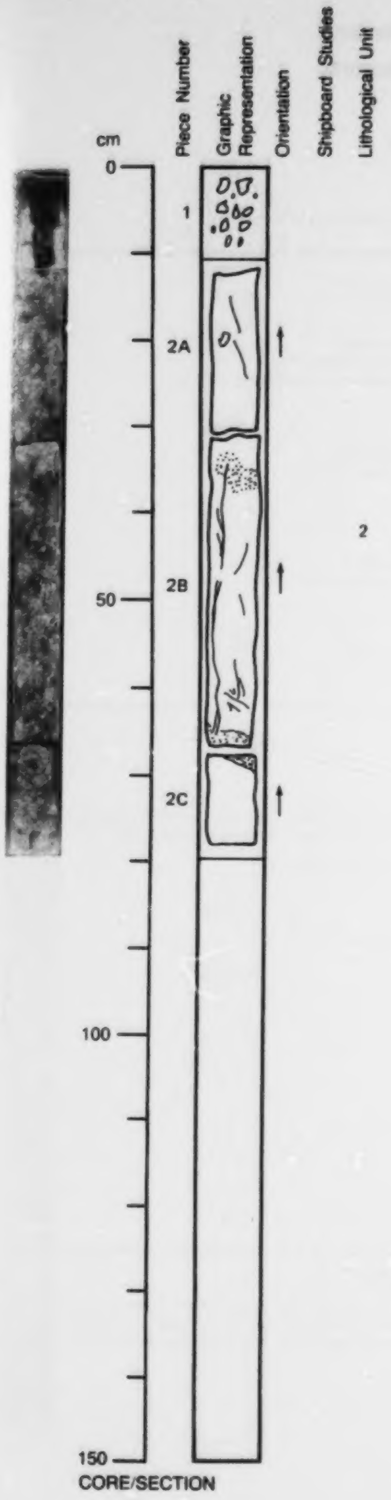
**Massive Olivine Gabbro**

**Pieces 1A-1G**

**COLOR:** Dark Gray.
**LAYERING:** None.
**DEFORMATION:** No apparent foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 0.5-4 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%-20% albitization.

Clinopyroxene—Mode: 45%.
Crystal size: 0.5-4 cm.
Crystal shape: Anhedral, some subhedral.
Preferred orientation: None.
Percent replacement: 10%-20% by amphibole.

Olivine—Mode: 5%, locally more abundant (20%) in upper part of section.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 30%-50% by orange-red oxides.
From 133 to 137 cm, olivine looks fairly fresh.
**SECONDARY MINERALOGY:**
Total percent: <5%-10%.
Texture: Amphibole replaces clinopyroxene partially, most plagioclase is fresh—small zone of albitization from 139 to 147 cm.
Percent vein material: <1%.
Vein material: Chlorite + actinolite along fractures, particularly between 80-90 cm.
**COMMENTS:** Plagioclase, clinopyroxene, and olivine modal proportions vary along the section.
Textures are igneous—interlocking crystals etc., not metamorphic.
29-33 and 129-132 cm: Concentrations of ilmenite(?).
Coarse grain-size intervals from 0-37, 56-62, and 90-130 cm.



## 118-735B-21R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-2C**

### Olivine to Olivine-Bearing Gabbro

**Pieces 1-2C**

**COLOR:** Gray.

**LAYERING:** Defined only by grain size, and then only approximately.
12-46 and 70-77 cm: Medium- to coarse-grained (2-10 mm).
47-64 cm: Very coarse-grained (5-25 mm).
34-36 and 65-66 cm: Fine- to medium-grained patches (1-3 mm).
In the case of 65-66 cm, diagonally across Pieces 2B and 2C.

**DEFORMATION:** No foliation.
Piece 2B (62 cm): Small (3 mm) offset on fracture, dipping at 28°.

**PRIMARY MINERALOGY:**

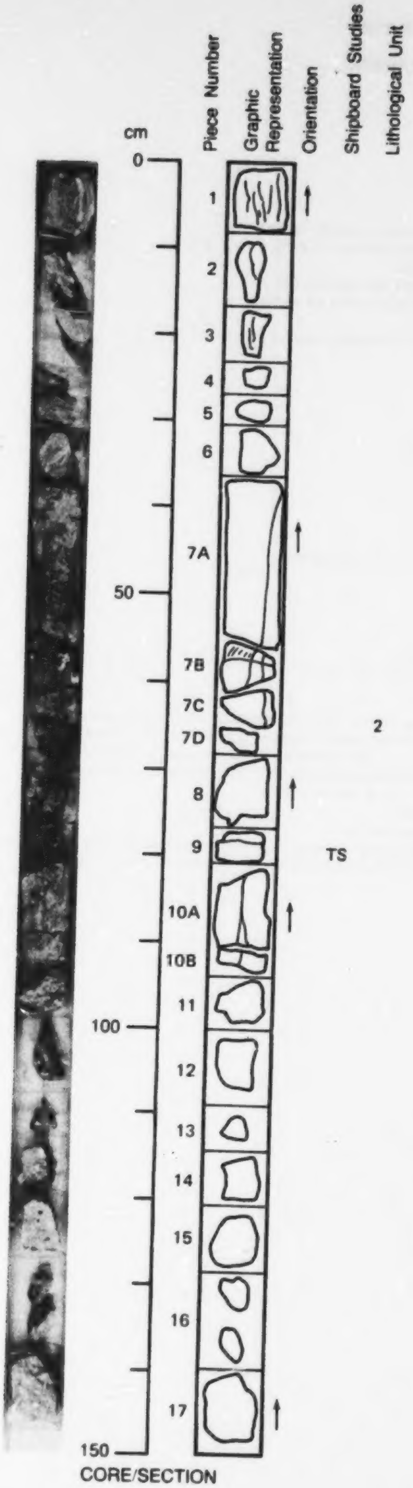
Plagioclase—Mode: 50%.
Crystal size: 1-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Minor albitization.

Clinopyroxene—Mode: 45%.
Crystal size: 1-25 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Sporadic alteration to amphibole.

Olivine—Mode: 2%-5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 30%-100% by chlorite, talc, and tremolite.

**SECONDARY MINERALOGY:**
Total percent: 70%.
Texture: Mostly along near-vertical veins from 65-70 cm. Amphibolitized clinopyroxene near vein, large, whitish, talc-tremolite olivine pseudomorphs at 20 cm. Vein filling looks like fine amphibole-plagioclase mix, perhaps with some epidote. Plagioclase has a whitish cast on left side of vein (looking at core); is probably partially albitized. Amphibolitization is common on other steeply dipping shorter veins throughout the core.
Percent vein material: Not determined.
Vein material: Fine amphibole-plagioclase mix.

**COMMENTS:** 0-10 cm: Altered gabbroic fragments. No orange pseudomorphs of olivine. Coarse- to fine-grained transitions appear igneous—intergrown crystals and gradational (though rapid) change.



**118-735B-22R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-17**

### Foliated Metagabbro/Mylonitic Metagabbro

**Pieces 1-6**

**COLOR:** Gray with white streaks, some orange brown porphyroclasts.
**LAYERING:** None.
**DEFORMATION:** Pieces 1 and 3: Mylonitic. Pieces 2 and 4-6: Porphyroclastic to augen gneissic. Piece 1: Foliation 90° and somewhat bent.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 50%-60%.
Crystal size: Variable, up to 2 cm.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Crystal shape marks foliation.
Percent replacement: Extensive replacement by amphibole.

Plagioclase—Mode: 40%-50%.
Crystal size: Variable.
Crystal shape: Porphyroclasts and neoblasts.
Preferred orientation: Crystal shape marks foliation.
Percent replacement: Moderate.

Olivine—Mode: 0%-10%.
Crystal size: Not determined.
Crystal shape: Porphtroclasts and neoblasts.
Preferred orientation: Crystal shape marks foliation.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: Moderate.
Texture: Amphibole replaces clinopyroxene.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Ilmenite accentuating banding. Iron-oxyhydroxides in cores of some porphyroclasts.

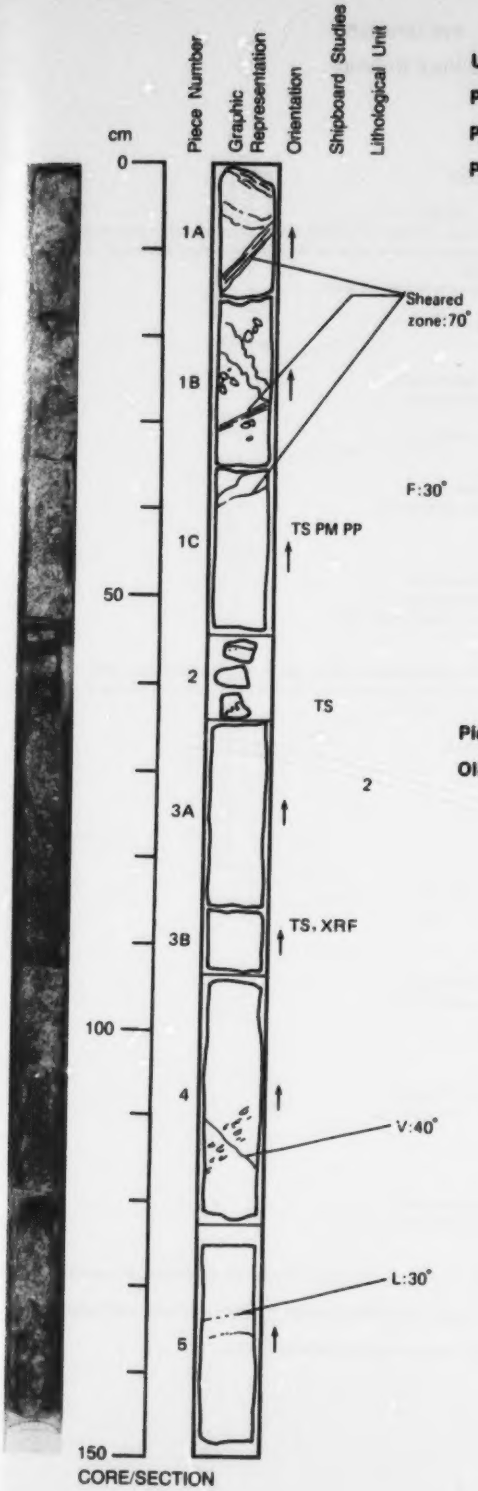
### Massive Gabbro

**Pieces 7A-17**

**COLOR:** Mainly gray, but green near and in amphibole veins. Pegmatite has white plagioclase, dark to black amphibole. Pieces 10 and 17: Orange altered porphyroclasts (oxidized).
**LAYERING:** None observed.
**DEFORMATION:** Slight. Granulated in amphibole-rich fractures.
**PRIMARY MINERALOGY:**
Clinopyroxene—Mode: 40%-50%.
Crystal size: 2 cm.
Crystal shape: Large oikocrysts, anhedral.
Preferred orientation: None.
Percent replacement: Moderate.

Plagioclase—Mode: 50%-55%.
Crystal size: Variable.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive.

Olivine—Mode: 0%-5%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pieces 8-12: Green amphibole near fractures replacing clinopyroxene; especially amphibole and chlorite(?) on fracture surfaces.
Percent vein material: Not determined.
Vein Material: Pieces 7, 10, 11, 14, and 15 locally cut by fractures of green amphibole plus a soft white mineral. One vein, or zone of amphibole. Plagioclase "pegmatite" in Piece 7B.
**COMMENTS:** Piece 7: Primary grain size variation well shown. Piece 7B: Coarse-grained. Piece 7A: Finer-grained toward bottom.



118-735B-22R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-5**

**Partly Sheared Metagabbro (Olivine-Bearing)**

**Pieces 1 and 2 (top)**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Weak except along a few 0.2- to 2-cm-thick, 30°-70° inclining shear zones.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 2 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: 5% by sodic plagioclase.

Clinopyroxene—Mode: 40%.
Crystal size: 0.2-1.5 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: 15% by amphibole.

Olivine—Mode: 1%-3%.
Crystal size: 0.2-7 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 2% by tremolite + mica or talc + opaque grains.
**SECONDARY MINERALOGY:**
Total percent: <20%.
Texture: Amphibole especially abundant in sheared zones. Clinopyroxene more extensively replaced by amphibole in upper part of this section. Sheared zone contains abundant opaque mineral.
Percent vein material: None except for thin shear zone.
Vein material: None.

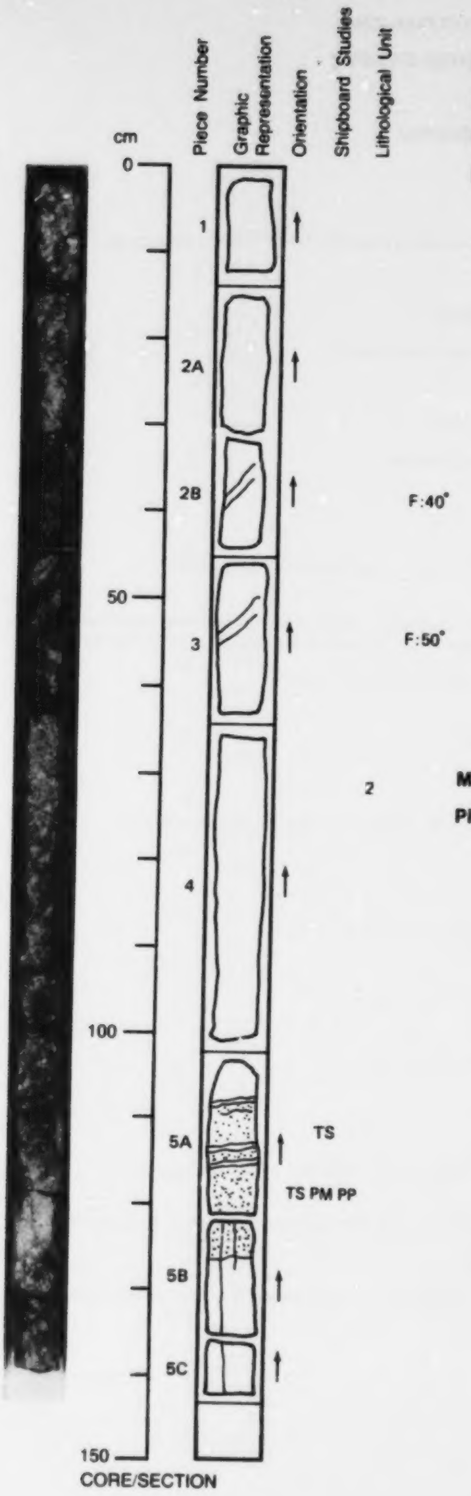
**Pieces 2 (middle)-5**

**Olivine Gabbro**

**COLOR:** Gray, mottled.
**LAYERING:** Vague layering dipping at ~30°. Locally weak magnetic foliation in Piece 4.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 2 cm.
Crystal shape: Subhedral.
Preferred orientation: None except for Piece 4.
Percent replacement: None.

Clinopyroxene—Mode: 40%.
Crystal size: 3 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 2%-5% by amphibole.

Olivine—Mode: 3%-10%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10% rimmed by thin tremolite + mica or talc aggregate.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Amphibole replaces clinopyroxene. Olivine is rimmed by white aggregates of tremolite + mica (or talc).
Percent vein material: None.
Vein material: None.
**COMMENTS:** Grain size and modal variation shows layering dipping 30°, nearly parallel to weak magmatic foliation.



**118-735B-22R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-5C

### Massive Olivine Gabbro

### Pieces 1-5A (top), 5B (bottom), and 5C

**COLOR:** Gray.

**LAYERING:** Bottom of Piece 3 to middle of Piece 4: Possible modal layering; upper part richer in plagioclase. Shows size grading, clinopyroxene varies from average of 3-5 mm to 15 mm. Dip of layering similar to foliation.

**DEFORMATION:** Pieces 2B and 3: Weak foliation apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred Orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 3-25 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 20% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 2-6 mm.
Crystal shape: Amoeboidal, anhedral.
Preferred orientation: Not determined.
Percent replacement: 5% by talc and tremolite.

**SECONDARY MINERALOGY:**

Total percent: 20%-30%.
Texture: Amphibole replacing clinopyroxene (20%), talc + tremolite replacing olivine (5%). Piece 3: White veins subparallel to foliation. Piece 5C: Possible sulfide in middle of amphibole vein.
Percent vein material: 0%-2%.
Vein material: Green amphibole.

### Microgabbro

### Pieces 5A (bottom) and 5B (top)

**COLOR:** Greenish gray.

**LAYERING:** None.

**DEFORMATION:** Weakly foliated.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

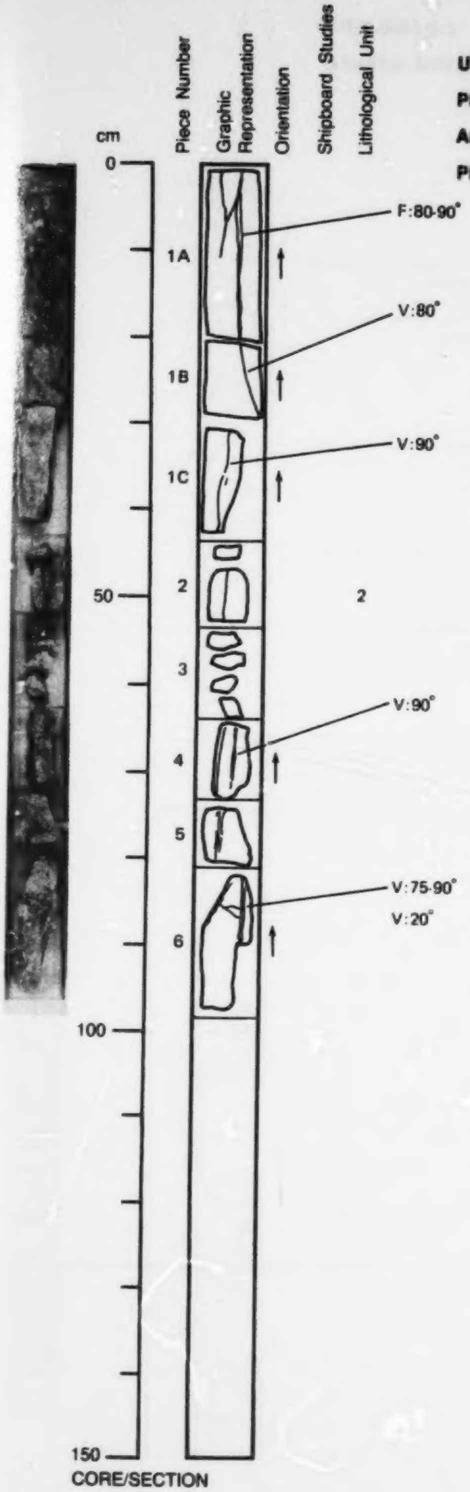
Clinopyroxene—Mode: 46%.
Crystal size: 0.5-2 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: 10% by amphibole.

Olivine—Mode: 4%.
Crystal size: 0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 2% by termolite and talc.

**SECONDARY MINERALOGY:**

Total percent: 10%-20%.
Texture: Olivine replaced by tremolite + talc (2%), clinopyroxene replaced by amphibole (10%).
Percent vein material: 2%.
Vein material: Two types: (1) green amphibole and (2) pegmatite veins with amphibole + white mineral.

**COMMENTS:** Location of metagabbro shown by dotted area on column.



cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1A
1B
1C
2
3
4
5
6
F:80-90°
V:80°
V:90°
V:90°
V:75-90°
V:20°
2
CORE/SECTION

## 118-735B-22R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-6**

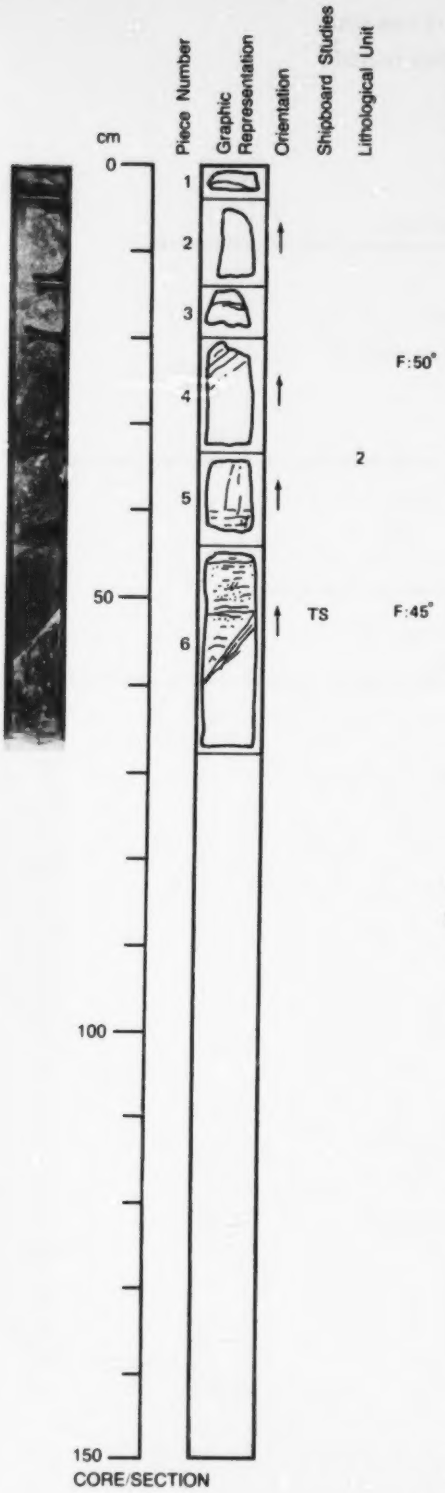
**Amphibole-Veined Metagabbro**

**Pieces 1A-6**

**COLOR:** Gray to greenish gray.
**LAYERING:** Grain-size variation suggests layering.
**DEFORMATION:** Weak except along amphibole veins having slight slip component.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: Up to 20 mm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: 5% by sodic plagioclase.

Clinopyroxene—Mode: 35%.
Crystal size: up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 5%-15% by amphibole. Piece 1: minor replacement. Pieces 2-6: Extensive replacement.

Olivine—Mode: 1%-4%.
Crystal size: Up to 10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: >20% by tremolite + talc or mica.
**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: Not determined.
Percent vein material: Abundant.
Vein material: Nearly vertical, 0.2- to 3-mm-thick amphibole veins with abundant slip components.



**118-735B-23R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-6**

**Massive Olivine-Bearing Gabbro**

**Pieces 1-5, and 6 (lower two-thirds)**

**COLOR:** Medium gray.
**LAYERING:** Not determined.
**DEFORMATION:**
Pieces 1, 3, and lower half of Piece 6: No foliation.
Pieces 2, 4, and 5: Weak foliation.
Piece 4 (upper left): Mylonitic band.
Pieces 1 and 6 (lower part): Coarse fraction.
Pieces 2-5: Less coarse-grained.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 2.5 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 43%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <70% by green amphibole.

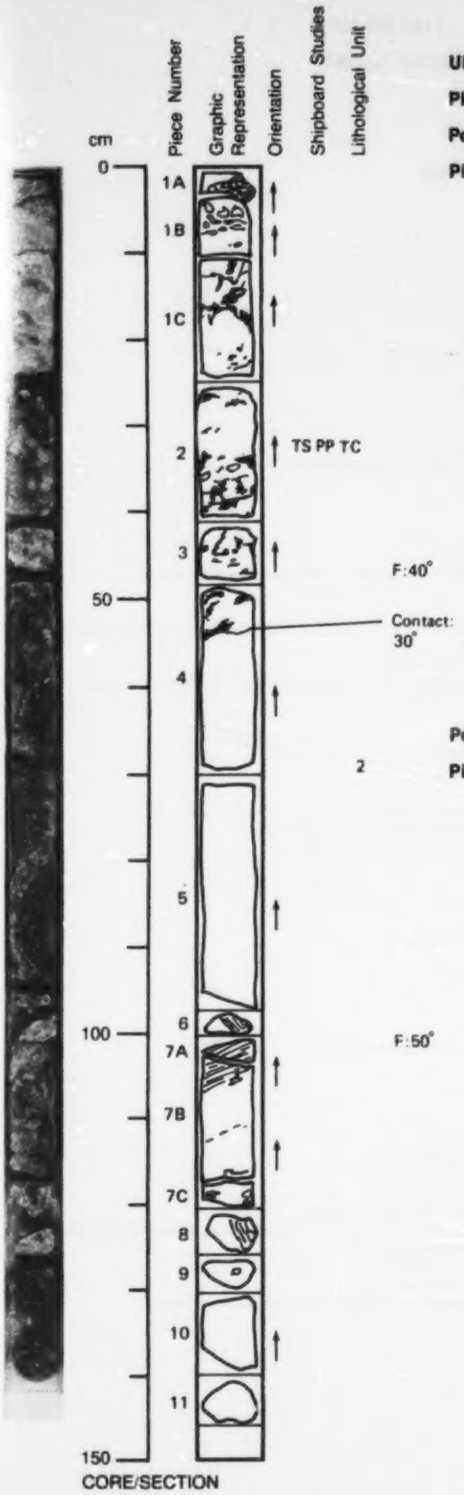
Olivine—Mode: 2%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture:
Piece 4: Olivine replaced by iron oxides and clays.
Piece 2: Some greenish-white minerals (talc?).
Piece 5: Clinopyroxene partially replaced by brownish mineral.
Pieces 5 and 6 (adjacent to microgabbro): Sulfides, + albite.
Piece 6: Mylonitic small band (inclining 45°), with white secondary mineral.
Percent vein material: Few veinlets.
Vein material: Amphibole + sulfides.

**Microgabbro**

**Piece 6 (upper one-third)**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 0.2-0.9 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 0.3-1.0 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Up to 50% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <10%
Texture: Sulfides dispersed throughout. Contacts with massive coarse-grained gabbro relatively sharp and horizontal.
Percent vein material: Not determined.
Vein material: Not determined.



118-735B-23R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-11

### Porphyroclastic Metagabbro

### Pieces 1A-1B (top), 6-7B (top)

**COLOR:** Gray to black.
**LAYERING:** Not determined.
**DEFORMATION:** Pieces 1A and 1B: Slightly enriched in opaque minerals (magnetite and ilmenite) that show foliation, probably represents sheared part (5 cm thick) of pegmatitic and olivine gabbro. Pieces 7A and 7B show foliation with 50° dip.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 50 mm.
Crystal shape: Subhedral.
Preferred orientation: Parallel to the foliation.
Percent replacement: Trace.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 30 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: Parallel to the foliation.
Percent replacement: 10%-20% by amphibole.

Opaque mineral(?), magnetite or ilmenite—Mode: 5%-10%. Enriched in Pieces 1A and 1B.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral aggregate(?).
Preferred orienetation: Shows foliation.
Percent replacement: Almost none.
**SECONDARY MINERALOGY:**
Total percent: <30%.
Texture: Amphibole replaces clinopyroxene.
Percent vein material: Not determined.
Vein material: Not determined.

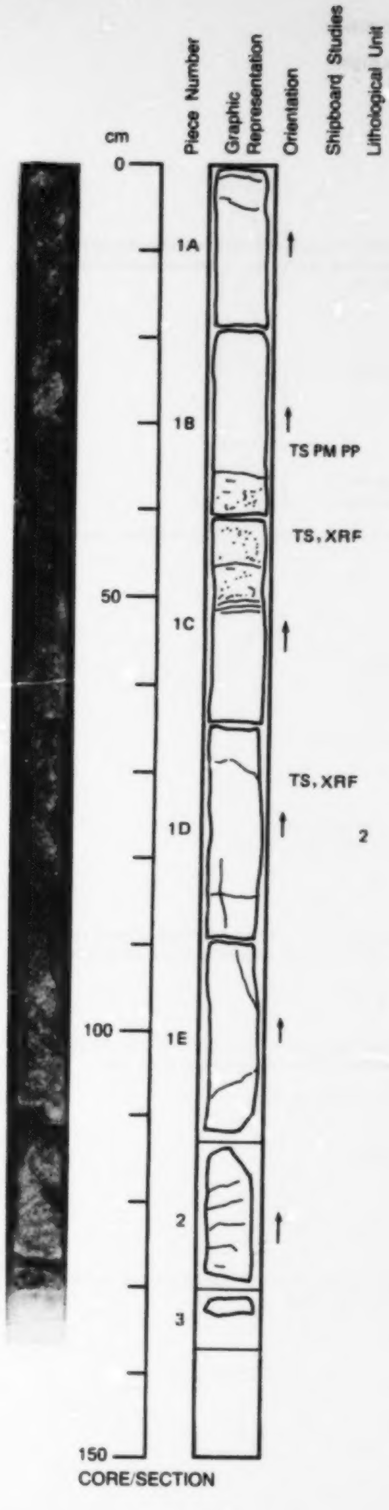
### Pegmatitic Coarse-Grained Gabbro

### Pieces 1B (bottom)-4 (top)

**COLOR:** Gray to black.
**LAYERING:** Interstitial magnetite and ilmenite show weak foliation.
**DEFORMATION:** Almost none except for weakly foliated and fractured.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 50 mm.
Crystal shape: Subhedral.
Preferred orientation: Slight orientation parallel to the foliation of porphyroclastic gabbro.
Percent replacement: Trace. Fractures filled with white minerals (prehnite, albite or talc?).

Clinopyroxene—Mode: 40%.
Crystal size: Up to 30 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: Slight orientation parallel to the foliation of porphyroclastic gabbro.
Percent replacement: 10%-20% by amphibole, particularly at bottom of the unit.

Opaque mineral(?), magnetite or ilmenite—Mode: 5%-10%.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral aggregate(?).
Preferred orientation: Shows weak foliation.
Percent replacement: Almost none.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Amphibole replaces clinopyroxene.
Percent vein material: Trace.
Vein material: Not determined.
**COMMENTS:** In magnetite and ilmenite aggregate, sulfide mineral is present. Contact with underlying olivine gabbro (finer-grained) is sharp and dips at 30°.



118-735B-23R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-3**

### Massive Olivine Gabbro

**Pieces 1A-2 (except between 35-50 mm)**

**COLOR:** Medium gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 20 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <10% by green amphibole on rims.

Olivine—Mode: 5%.
Crystal size: Up to 10 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Sometimes replaced by yellowish-brownish minerals.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Dispersed sulfide grains. Olivine relatively fresh looking, sometimes replaced by yellowish-brownish minerals.
Percent vein material: Not determined.
Vein material: Veinlets with green amphibole and/or sulfides. Talc and tremolite(?).

### Microgabbro (Olivine-Bearing)

**Pieces 1B and 1C (between 35-50 mm)**

**COLOR:** Medium gray.
**LAYERING:** Increase in grain size toward bottom.
**DEFORMATION:** Generally none, however, some shearing in Piece 1C.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 0.3 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 44%.
Crystal size: 0.3 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Up to 100% by amphibole.

Olivine—Mode: 1%.
Crystal size: 0.3 cm.
Crystal shape: Anhedral.
Preferred orienetation: None
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Up to 30%.
Texture: Sulfides dispersed in rock and in veinlets.
Lower boundary of microgabbro marked by small mylonitic band. Microgabbro might contain considerable amounts of amphibole(?).
Percent vein material: Not determined.
Vein material: Amphibole + sulfides.
**COMMENTS:** Lower boundary of microgabbro marked by a small mylonitic band.

### Foliated Olivine Gabbro

**Piece 3**

No description.

**118-735B-23R-3 (continued)**

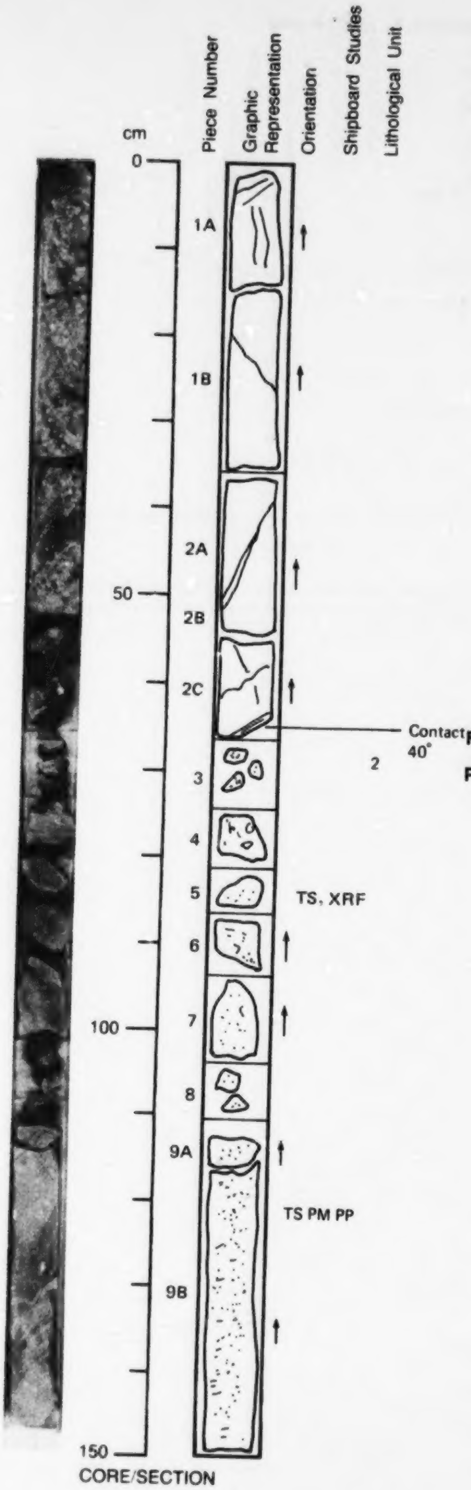
## Olivine Gabbro

### Pieces 4 (bottom)-5, and 7B (bottom)-11

**COLOR:** Gray.
**LAYERING:** No clear layering.
**DEFORMATION:** Piece 8: Weak foliation.
Pieces 9-11: Partly sheared and foliated.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 10 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Almost none.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Olivine—Mode: 5-7%.
Crystal size: Up to 20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%-30% by tremolite + mica, or by talc aggregate from the margins; locally oxidized.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Between olivine and plagioclase, white alteration zone is present, which may be due to olivine-plagioclase reaction with introduction of water. Pieces 9-11: Strongly altered. Olivine perfectly replaced by tremolite + mica or talc.
Percent vein material: Trace.
Vein material: Not determined.



## 118-735B-23R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-9B

### Massive Olivine Gabbro

### Pieces 1A-2C

**COLOR:** Medium gray.
**LAYERING:** None.
**DEFORMATION:** No deformation except a weak foliation at the top of Piece 1A.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%.
Crystal size: Up to 15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

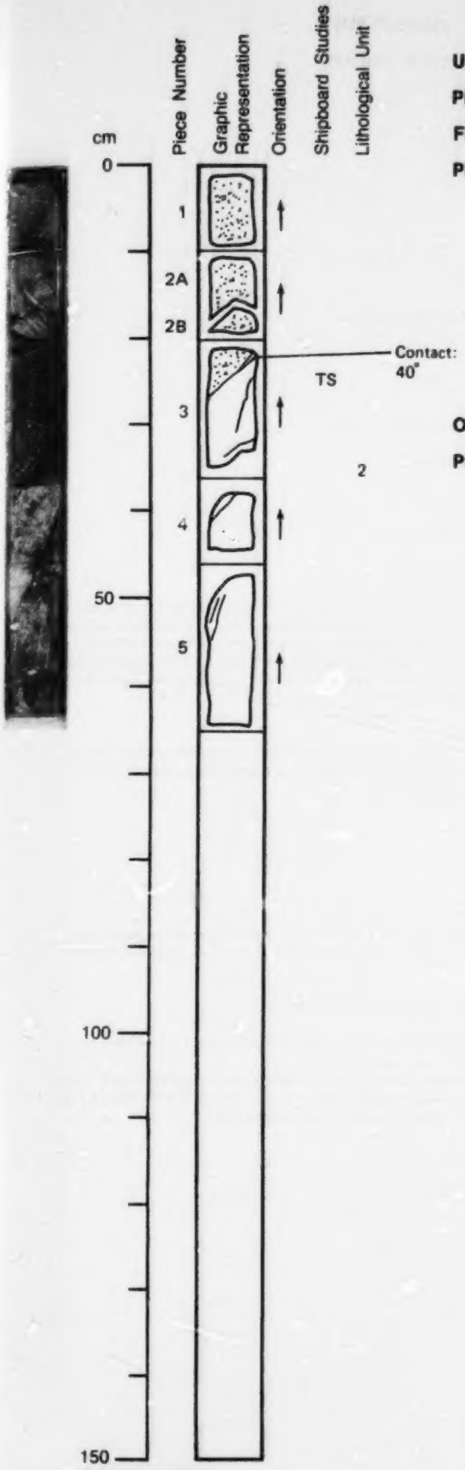
Clinopyroxene—Mode: 45%.
Crystal size: Up to 15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <5% by green amphibole on margins. Concentrations of alteration in Piece 1A.

Olivine—Mode: 5%-10%.
Crystal size: Up to 5 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Replacement: Pervasively replaced by talc and tremolite.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Clinopyroxene altered to amphibole on margins. Olivine pervasively replaced by talc and tremolite.
Percent vein material: Not determined.
Vein material: Veinlets of talc and tremolite in Piece 1.

### Fine-Grained Aphyric Basalt Dike

### Pieces 2C-9B

**CONTACTS:** Contact well-developed at bottom of Piece 2C (5 mm) dipping at 40°.
**PHENOCRYSTS:** <1% microphenocrysts; homogeneous distribution of plagioclase and olivine.
**GROUNDMASS:** Microcrystalline at contacts, fine-grained in center.
Plagioclase—50%, <0.3 mm, lath-shaped to subhedral, fresh(?).
Clinopyroxene—45%, <0.3 mm, anhedral, fresh(?).
[illegible]—<5%, <0.3 mm, skeletal, totally replaced by talc(?).
**COLOR:** [illegible] gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Dike.
**ALTERATION:** Slightly altered to clay minerals and talc(?).
**VEINS/FRACTURES:** Not determined.



**118-735B-23R-5**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-5

### Fine-Grained Aphyric Basalt Dike

### Pieces 1-3 (top)

**CONTACTS:** Contact well-developed at top of Piece 3 (5 mm) dipping at 40°.
**PHENOCRYSTS:** <1% microphenocrysts, homogeneously distributed of plagioclase and olivine.
**GROUNDMASS:** Aphanitic near contact in Piece 3, fine-grained in center.
  Plagioclase—50%, <0.2 mm, subhedral, fresh.
  Clinopyroxene—45%, <0.2 mm, anhedral, fresh.
  Olivine—<5%, <0.2 mm, euhedral, totally replaced by smectites.
**COLOR:** Gray.
**VESICLES:** Nonvesicular.
**STRUCTURE:** Dike.
**ALTERATION:** Slightly altered to smectites.
**VEINS/FRACTURES:** Not determined.

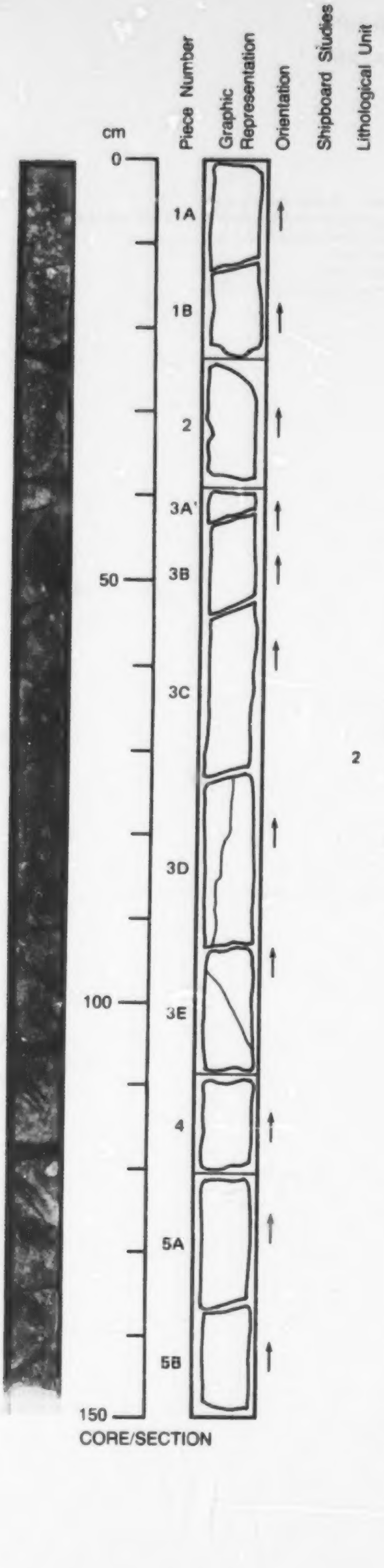
### Olivine-Bearing Gabbro

### Pieces 3 (bottom)-5

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Weakly foliated in places.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: 60%.
  Crystal size: 2-6 mm.
  Crystal shape: Subhedral.
  Preferred orientation: Not determined.
  Percent replacement: Not determined.

  Clinopyroxene—Mode: 36%.
  Crystal size: 2-10 mm.
  Crystal shape: Subhedral.
  Preferred orientation: Not determined.
  Percent replacement: 15% by amphibole.

  Olivine—Mode: 4%.
  Crystal size: 2-8 mm.
  Crystal shape: Anhedral.
  Preferred orientation: Not determined.
  Percent replacement: 5% by talc + tremolite
**SECONDARY MINERALOGY:**
  Total percent: 20%.
  Texture: Amphibole replacing clinopyroxene, talc + tremolite replacing olivine.
  Percent vein material: Not determined.
  Vein material: Not determined.



**118-735B-24R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-5B

### Amphibolitized Olivine Metagabbro

### Pieces 1-3C, and 3E (bottom)-5A

**COLOR:** Gray (pale green overtone).
**LAYERING:** None.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-35%.
Crystal size: 3-30 mm.
Crystal shape: Subhedral to anhedral granular.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-45%.
Crystal size: 3-30 mm.
Crystal shape: Subhedral to anhedral granular.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 0%-5%.
Crystal size: Not determined.
Crystal shape: Anhedral interstitial.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined, but generally extensive although variable, pervasive alteration.
Texture: Green amphibole rimming and pseudomorphing pyroxene. Amphibole also occurs as laths in plagioclase grains. Locally, where large clinopyroxene grains are replaced, the rock is vuggy with hollows lined with actinolite needles and filled with a white claylike material that expands when acid is added. Patches of interstitial ilmenite occur locally—with the appearance of a hydrothermal replacement.
Percent vein material: 1%.
Vein material: Amphibole.

**COMMENTS:** Subhedral to anhedral granular, grain size varies along core from coarse- to very coarse-grained, where there are patches of crystals exceeding 3 cm. Olivine appears distinctly interstitial.

### Feebly Foliated Metagabbro

### Pieces 3D-3E (top), and 5B

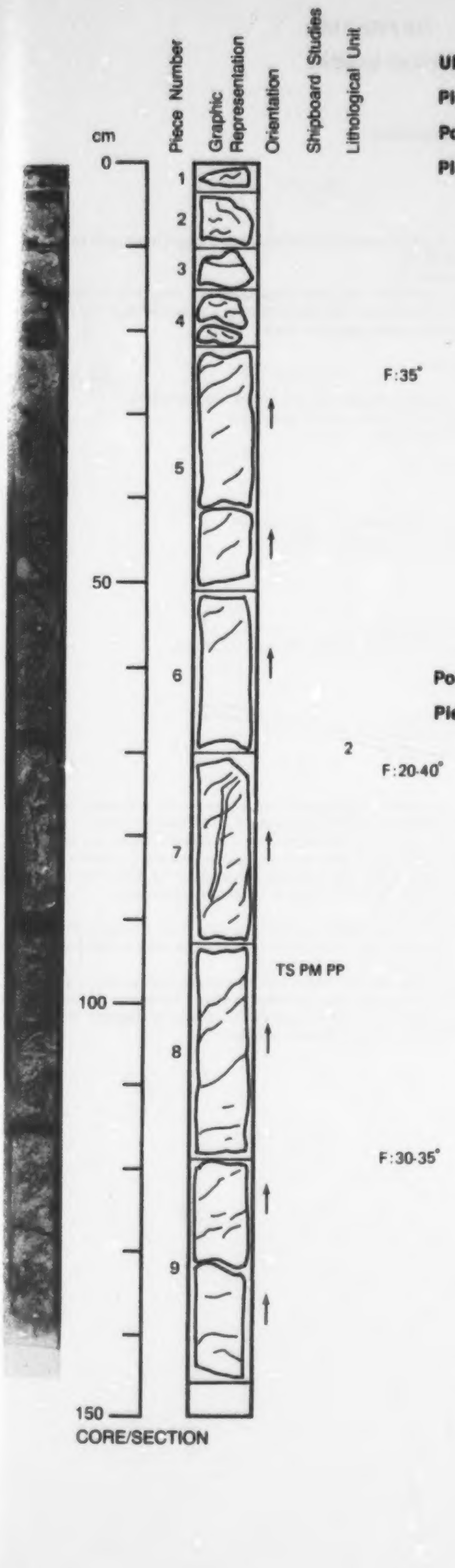
**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Locally, a clear foliation is present defined by medium-grained amphibiole and plagioclase elongated or stretched out along the plane of foliation. However, most of this zone is undeformed.
**PRIMARY MINERAOLGY:**

Similar to amphibolitzed olivine gabbro described above.

**SECONDARY MINERALOGY:**

Similar to amphibolitized olivine gabbro described above, except for the presence of accessory (<1%) pyrite, which occurs locally.

**COMMENTS:** Grain size ranges downward from coarse- to medium-grained and then back to coarse-grained. Piece 5B contains a wedge-shaped zone 1 to 15 mm thick and 80 mm long, inclined at 45°, rich in ilmenite (30%), intergrown with green amphibole.



## 118-735B-24R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-9B**

### Porphyroclastic Metagabbro

**Pieces 1-5A (top), 7, and 8**

**COLOR:** Grayish green.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by the flattening and deformation of plagioclase and pyroxene porphyroclasts, and by grain-size variations forming fine-grained matrix. Grain sizes: porphyroclasts—3-15 mm; Neoclasts: < 3mm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by prehnite.

Clinopyroxene—Mode: 60%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.

Ilmenite—Mode: 3%-10% in Pieces 3, 4, and 8; spaces around silicate minerals.
**SECONDARY MINERALOGY:**
Total percent: At least 25%.
Texture: Green amphibole pseudomorphs after pyroxenes or rimming amphibole pseudomorphs.
Plagioclase is partly prehnitized in Piece 7.
Percent vein material: Not determined.
Vein material: Amphibole + plagioclase. Subvertical veins filled by amphibole in Piece 7.

### Poorly Foliated Ilmenite Metagabbro

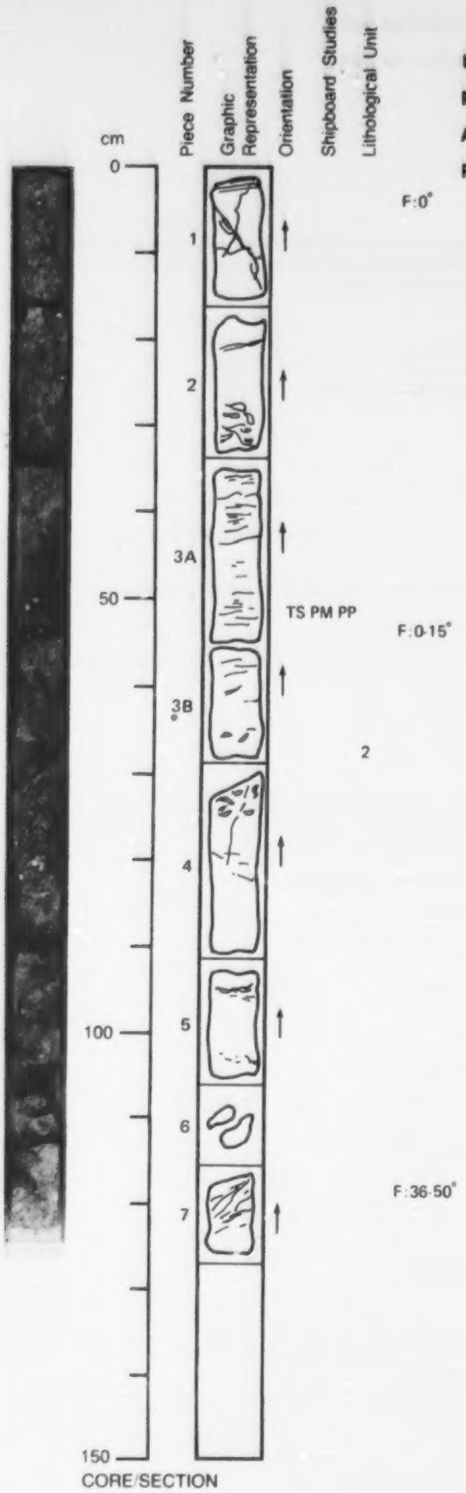
**Pieces 5A (bottom)-6, 9A and 9B**

**COLOR:** Dark gray green.
**LAYERING:** None.
**DEFORMATION:** Weak foliation defined by preferred orientation of pyroxene and plagioclase. Secondary amphibole veinlets enhance the foliation. Original grain size is preserved, except for some granoblasts of plagioclase, olivine, and pyroxene.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-60% (including granoblasts).
Crystal size: 1-4 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Weak.
Percent replacement: 50%.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: 30% by amphibole.

Olivine—Mode: Trace.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not seen.
Percent replacement: 10%.

Ilmenite—5%-10%.
Crystal size: <1 mm.
Crystal shape: Granular.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 50%.
Texture: Pseudomorphic. Green amphibole pseudomorphs after clinopyroxene. Green amphibole replaced by lighter green amphibole. Scattered sulfides throughout core.
Percent vein material: Not determined.
Vein Material: In Pieces 9A and 9B, veins of dark amphibole, 2- to 4-mm-thick, injected parallel to the foliation. Some thin plagioclase veins, few millimeters long and 1-mm-thick, one injected along the foliation plane.



### 118-735B-24R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-7

### Amphibolitized Olivine-Bearing Metagabbro

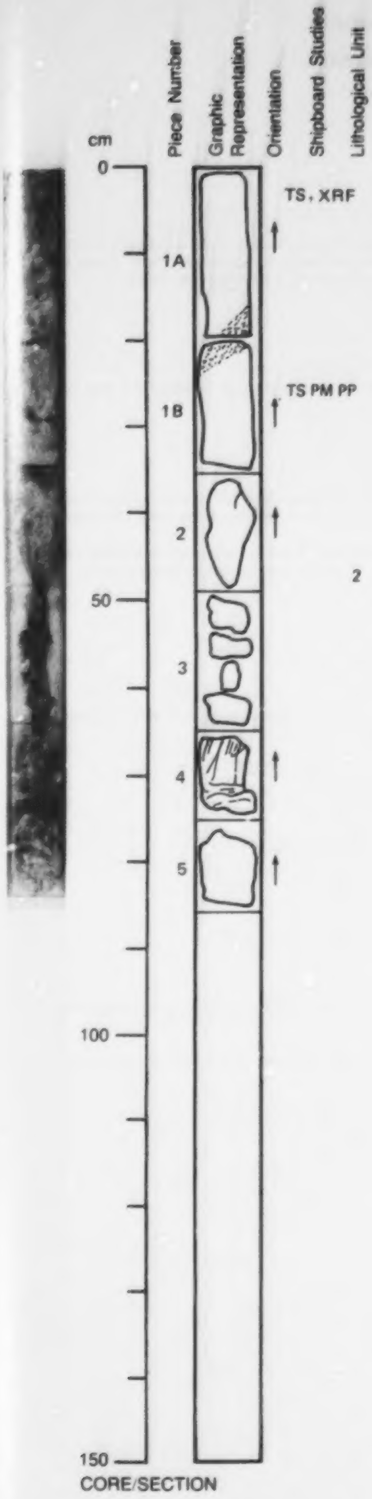
### Pieces 1-7

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Alternating zones of deformation and nondeformation. Slight lamination of coarse-grained section between 25-35 cm.
Horizontal mylonitic zone at 0-1 cm.
Foliation between 38-64 cm defined by elongated plagioclase and amphibole in finer-grained section at 38-60 cm, and porphyroclastic textures at 56-68 cm. A well-foliated to mylonitic band between altered, coarser-grained gabbro in Piece 7.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Up to 40%.
Crystal size: 3-30 mm.
Crystal shape: Anhedral. Fractured, veined with amphibole in many places.
Preferred orientation: Aligned in foliation, where developed.
Percent replacement: Not determined.

Clinopyroxene—Mode: Up to 40%.
Crystal size: 2-30 mm.
Crystal shape: Anhedral.
Preferred orientation: Aligned in foliation, where developed.
Percent replacement: Extensive amphibole replacement.

Olivine—Mode: 1%-4%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Extensive replacement by serpentine and talc.

Ilmenite(?)—Mode: 5%.
Crystal size: 0.1-0.5 mm.
Crystal shape: Anhedral in Piece 2B.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Up to 80%.
Texture: Dark green, green-gray amphibole replaces clinopyroxene. Piece 6. nearly completely replaced. Somewhat more extensively altered in sheared zones. There are zones of abundant opaques associated with fine pyrite (1-2 mm). Opaques are probably ilmenite, are anhedral, 2-5 mm in size, and are interstitial to the other phases. Opaques are most common (10%-15%) in the lower parts of Pieces 2B and 3B, and in the top part of Piece 4B. These are zones with moderate to extensive amphibolitization and slight to moderate deformation.
Percent vein material: Not determined.
Vein material: Veins and fractures are common. Most commonly filled with prismatic green amphibole needles at 24, 52, and 94 cm, or a mixture of amphibole and a greenish-white mineral—probably albite with mixed amphibole or epidote.
**COMMENTS:** This section appears to have been an olivine gabbro, perhaps with a primary grain-size variation, which has been variously deformed and amphibolitized. Percent of primary minerals varies along core from average of 2% to 70%, depending on degree of alteration. Where core is freshest (2-33 cm), 80%-89% of primary minerals remain.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3
4
5
TS, XRF
TS PM PP
2
CORE/SECTION

### 118-735B-24R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

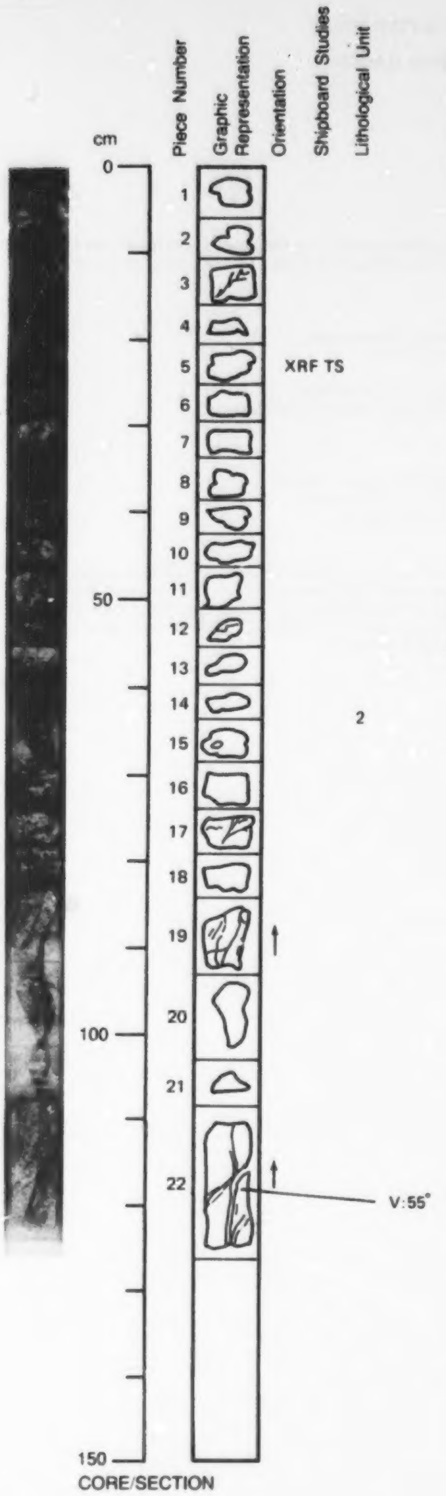
**Pieces 1A-5**

**Massive Gabbro**

**Pieces 1A-5**

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** Piece 4 poorly foliated, approximately horizontal, defined by flattened plagioclase, clinopyroxene, and amphibole. Also flattening of crystals in fragment of rubble from Piece 3; other pieces are massive.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: ~1 to 20 mm. Mostly coarse-grained.
Fine-grained interval between 18 to 24 cm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in plane of foliation.
Percent replacement: Variable, 5%-70% by sodic plagioclase.

Clinopyroxene—Mode: 45%.
Crystal size: 1-20 mm.
Crystal shape: Subhedral to euhedral, some subophitic.
Preferred orientation: Elongate in plane of foliation.
Percent replacement: 0%-75% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 5%-70%.
Texture: For interval between 0-48 cm, clinopyroxene is partially replaced along grain edges by green amphibole. Thin fractures also filled by green amphibole. Plagioclase relatively fresh. Below 48 cm, alteration increases. Plagioclase 60%-70% albitized, clinopyroxene 75% replaced by amphibole. Piece 4 is cut by numerous thin veins of green amphibole. Accumulations of ilmenite and pyrite in Piece 5.
Percent vein material: <5%.



## 118-735B-25R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-22

### Amphibolite/Amphibolitized Metagabbro

### Pieces 1-18

**COLOR:** Dark green-black.
**LAYERING:** None.
**DEFORMATION:** Foliation weak to nonexistent. Deformation appears slight. Amphibole is not strongly oriented and is growing into vuggy cavities as needlelike aggregates. Piece 10 may have a small brecciated zone in it. Plagioclase in Piece 1 is broken and granulated.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 10%-40%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Appears somewhat broken and albitized. Grains have a granular whitish/clear appearance. 80% recrystallized.

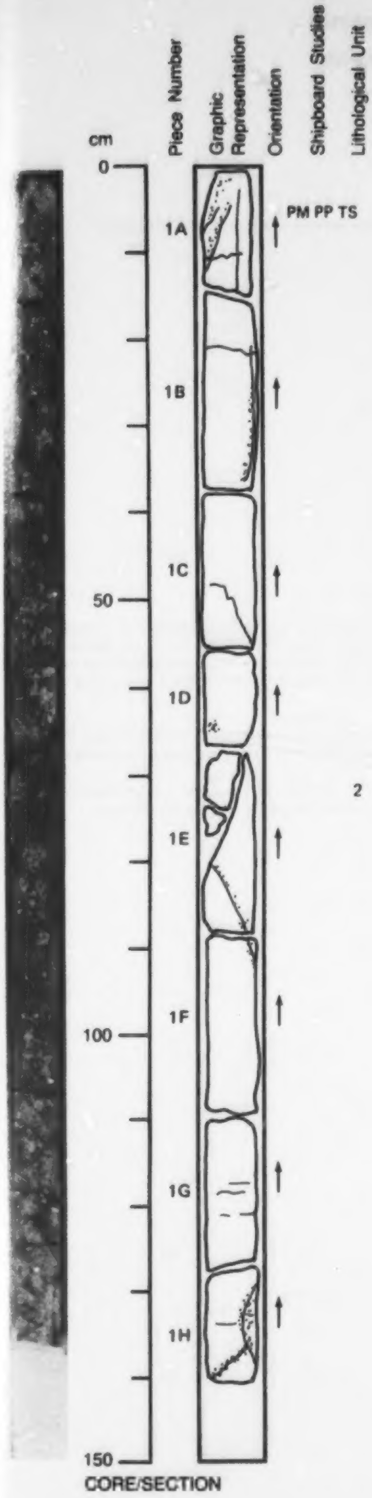
No remnant of clinopyroxene or olivine.
**SECONDARY MINERALOGY:**
Total percent: Up to 90%
Texture: Largely dark green amphibole 1-5 mm in size. Granular aggregates replacing pyroxene and plagioclase. Highly porous with numerous small cavities. Some albite after plagioclase.
Percent vein material: Not determined.
Vein material: Veins and open fractures in Pieces 3 and 17: Amphibole needles and albite (white mineral) in Piece 17. Piece 17 has needles of a white mineral filling a cavity.

### Medium-Grained Amphibolitized Metagabbro

### Pieces 19-22

**COLOR:** Not determined.
**LAYERING:** None.
**DEFORMATION:** Small offset on fracture in Piece 19. Weak foliation in parts of Piece 22 parallel to a steeply dipping fracture.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%.
Crystal size: 2-4 mm (equigranular).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive replacement by albite.

Clinopyroxene—Mode: 60%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60%-80% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Up to 50%-60%.
Texture: Green amphibole after clinopyroxene; amphibole is a lighter green than the amphibole in the upper one-half of the core.
Percent vein material: < 10%.
Vein material: Soft greenish-white material fills veins and covers fracture surfaces in Pieces 19 and 22.



**118-735B-25R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1H**

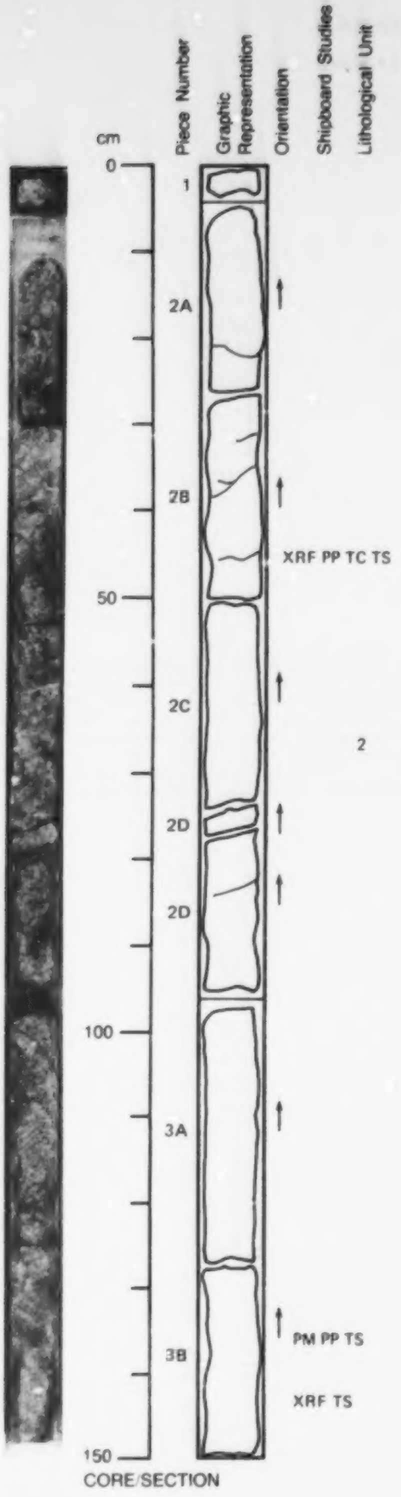
**Massive Olivine Gabbro**

**Pieces 1A-1H**

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** No foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20%-40% by albite.

Clinopyroxene—Mode: 45%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50%-80% by amphibole on rims.

Olivine—Mode: 0%-5%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 75% by oxides.
**SECONDARY MINERALOGY:**
Total percent: 15%-25%.
Texture: Not determined.
Percent vein material: 3%-4%.
Vein material: Core contains thin veins of chlorite(?) + actinolite in most pieces, but particularly at the top of Piece 1A, along the side of Piece 1B, and along the side and bottom of Piece 1H. These veins are generally oriented near-vertically. Plagioclase is more altered to albite(?) adjacent to these veins for a distance of 1 cm or more on either side. A few concentrations of ilmenite are present between 69-80 cm, where grain size is coarsest. Thin ($\ll$1 mm) veins of white minerals, nearly horizontal in Pieces 1B, 1G, and 1H.
**COMMENTS:** Grain size varies along length of core; pieces are all very coarse-grained, but particularly large between 70-79 cm. Grains show interlocking igneous textures, not deformed in general.



**118-735B-25R-3**

**UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO**

**Pieces 1-3B**

**Olivine Gabbro**

**Pieces 1-3B**

**COLOR:** Gray to greenish gray.
**LAYERING:** None, but Piece 3B (126-150 cm) is finer-grained, sharp granulometric contact.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-58%.
Crystal size: 1-5 mm; 1-3 mm in Piece 3B.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: 0%.

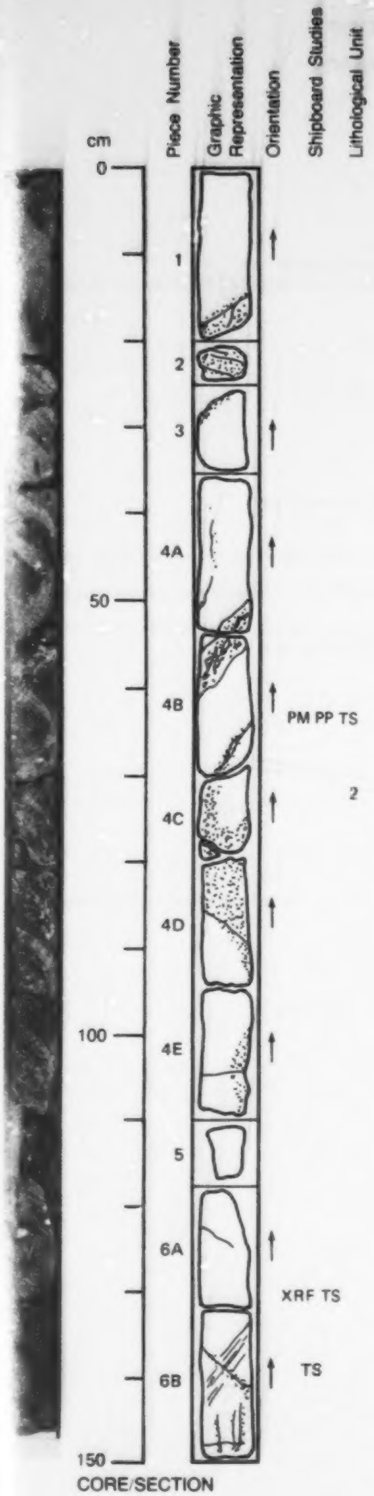
Clinopyroxene—Mode: 40%.
Crystal size: 2-14 mm; 2-4 mm in Piece 3B.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 0%.

Olivine—Mode: 2%-5%.
Crystal size: 1-4 mm; 1 mm in Piece 3B.
Crystal shape: Irregular (rounded).
Preferred orientation: None.
Percent replacement: 0%.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Pseudomorphic. Green amphibole: Pseudomorph after clinopyroxene, in pockets related to late-stage veins. Veins are 1 mm to 1 cm thick in Pieces 2A, 2B, 2C. Serpentine: Light blue to green, replaces olivine in a web texture where very fine-grained magnetite is intermixed. Talc: May be present. Chalcopyrite: Spot 2 × 4 mm in Piece 1, related to large green amphibole.
Percent vein material: <5%
Vein material: Veins are filled by green amphibole and plagioclase. Gabbro is more altered in area cut by these veins. Cracks are filled by chlorite or serpentine (amorphous material, blue green color).

**COMMENTS:** Very fresh rock. Olivine and plagioclase are found in inclusions in large oikocrystic clinopyroxene, and in clinopyroxene and plagioclase of the goundmass minerals.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4A
4B
4C
4D
4E
5
6A
6B
PM PP TS
2
XRF TS
TS
CORE/SECTION

**118-735B-26R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

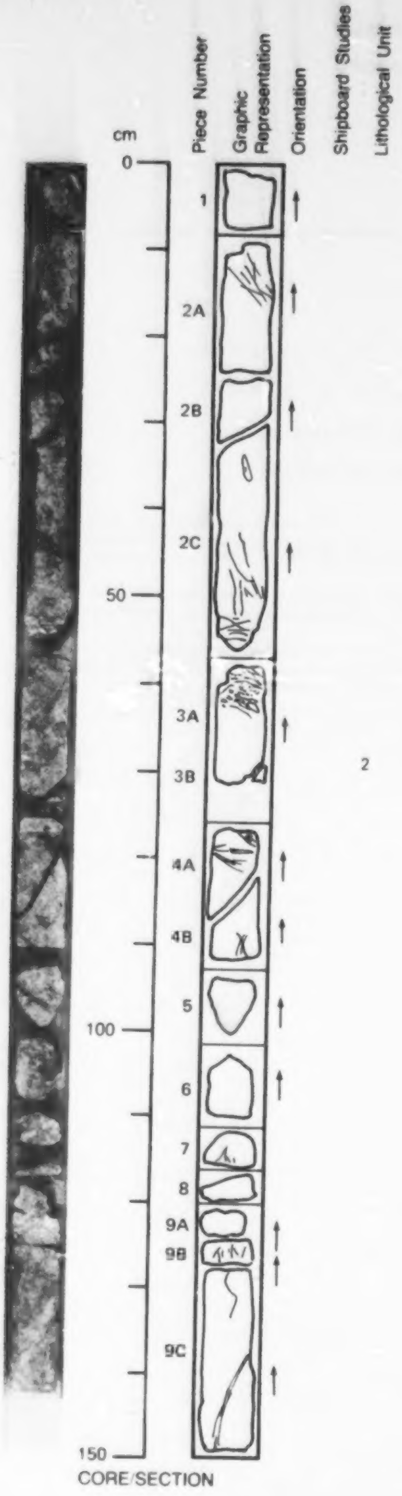
**Pieces 1-6B**

**Massive Gabbro**

**Pieces 1-6B**

**COLOR:** Dark gray.
**LAYERING:** Piece 6B: Possible primary layering represented by transition to microgabbro.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <1 mm-1 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent alteration: 0%-5% by albite.

Clinopyroxene—Mode: 50%.
Crystal size: <1 mm-1 cm.
Crystal shape: Anhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent alteration: 50%-75% replaced by green amphibole.
**SECONDARY MINERALOGY:**
Total percent: 25%-38%.
Texture: Partial replacement (50%-75%) of clinopyroxene by green amphibole. Total replacement in areas of veins and amphibolite zones. Plagioclase partially albitized around rims. Albitization more extensive in three intervals: 18-28 cm, 15-62 cm, and 77-90 cm.
Percent vein material: 20%.
Vein material: Vertical to steeply inclined veins typically filled by green amphibole. Thinner veins, near horizontal, filled by greenish-white mineral, possibly some chlorite or talc + tremolite.
**COMMENTS:** Grain size varies along the length of the core from fine-grained microgabbro (Piece 6B) to coarse-grained (all other pieces). Alteration of primary phases is also variable, greatest adjacent to albite + amphibole veins (Pieces 1, 2, and 3). Subophitic texture.



**118-735B-26R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-9C

### Amphibolitized Olivine Gabbro

### Pieces 1-4B, and 9C

**COLOR:** Gray to greenish gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Some granulation of plagioclase.
 Piece 2C (52-54 cm): Weakly foliated amphibole-albite zone.
 Piece 4A (75-77 cm): Small cataclastized zone associated with amphibole vein on lower side.
**PRIMARY MINERALOGY:**
 Plagioclase—Mode: 40%-60%.
 Crystal size: 2-20 mm.
 Crystal shape: Anhedral.
 Preferred orientation: None.
 Percent alteration: Moderate replacement by albite.

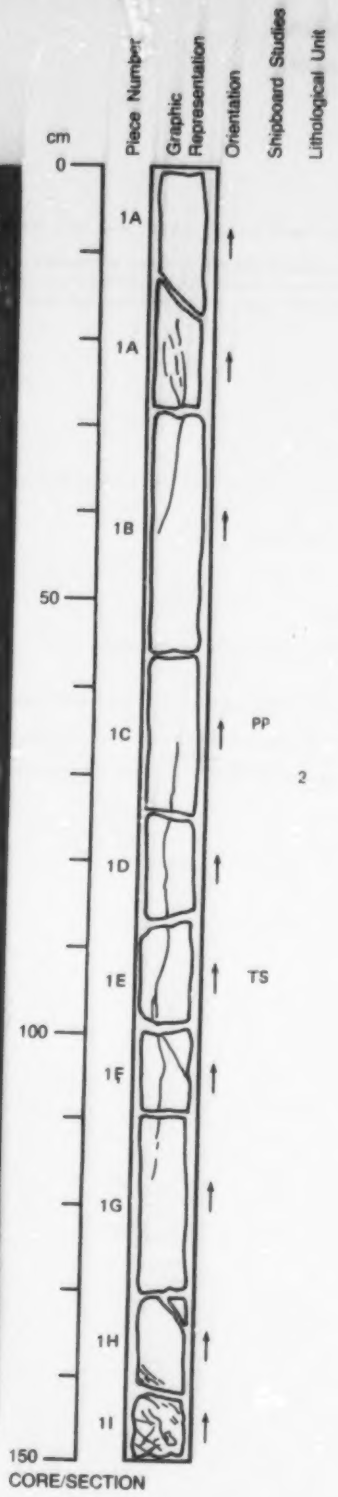
 Clinopyroxene—Mode: 60%-40%.
 Crystal size: 2-28 mm.
 Crystal shape: Anhedral.
 Preferred orientation: None.
 Percent alteration: Moderate replacement by amphibole.
**SECONDARY MINERALOGY:**
 Total percent: 40%-60%.
 Texture: Replacement of clinopyroxene and plagioclase by amphibole and albite, respectively.
 Percent vein material: <5%.
 Vein material: Pieces 2A (10-15 cm), 4B (90 cm), and 9C (140-150 cm): Veins and vuggy cavities filled with fibrous amphibole.
**COMMENTS:** Medium- to coarse-grained. Similar protolith to massive gabbro in Section 117-735B-25R-4
 Pieces 2C and 3A (55-60 cm): Fine-grained igneous zone.

### Amphibolitized Gabbro

### Pieces 5-9B

**COLOR:** Green gray to white.
**LAYERING:** None.
**DEFORMATION:** Weak to no foliation.
**PRIMARY MINERALOGY:**
 Plagioclase—Mode: 60%-40%.
 Crystal size: <1 cm.
 Crystal shape: Anhedral.
 Preferred orientation: None.
 Percent alteration: Extensive alteration. Albitized with translucent relict calcic zones.

 Clinopyroxene—Mode: 40%-60%.
 Crystal size: <1 cm.
 Crystal shape: Anhedral.
 Preferred orientation: None.
 Percent alteration: 100%, replaced by dark amphibole.
**SECONDARY MINERALOGY:**
 Total percent: Extensive to complete.
 Texture: Not determined.
 Percent vein material: 1%.
 Vein material: Sodic plagioclase + actinolite.



### 118-735B-28R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-1I

### Gabbro

### Pieces 1A-1I

**COLOR:** Gray.
**LAYERING:** Size grading present.
**DEFORMATION:** 2-cm-thick gneissic zone at 138-146 cm, remainder undeformed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-65%.
Crystal size: 0.5-1.0, locally up to 20 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: 4% by amphibole, albite, and chlorite.

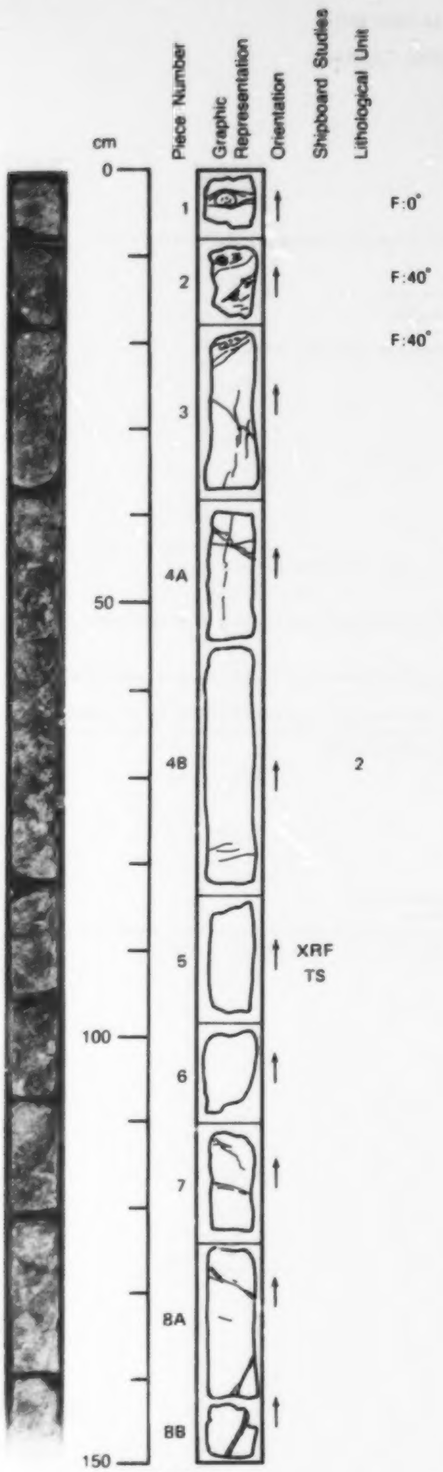
Clinopyroxene—Mode: 35%-45%.
Crystal size: 3 to 20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replecement: 20% by amphibole.

Olivine—Mode: <1%.
Crystal size: 0.5-2 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: 100% by calcite, chlorite, and tremolite.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Locally amphibolitized and albitized around long subvertical amphibolite veins (20-40 cm and 66-115 cm).
Percent vein material: 1%.
Vein material: Amphibole. Fracture in Piece 1A at 15 cm has amphibole lineation in vein inclined at 58°.
**COMMENT:** Grain size varies greatly along the section, ranging from patches of microgabbro (63-101 cm) to coarse gabbro (0-63 cm and 101-138 cm). Large clinopyroxene oikocrysts enclose 0.5 to 1.0 cm euhedral to subhedral plagioclase laths.

### Autoclastic Gabbro Breccia

### Piece 1I (142-150 cm)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Coarse brecciated gabbro (in-situ).
**PRIMARY MINERALOGY:** See gabbro above.
**SECONDARY MINERALOGY:** Angular gabbro clasts in a matrix of plagioclase. Gabbro clasts more altered with interstitial amphibole and small 3 × 1 mm patches of pyrite.



## 118-735B-26R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-8B**

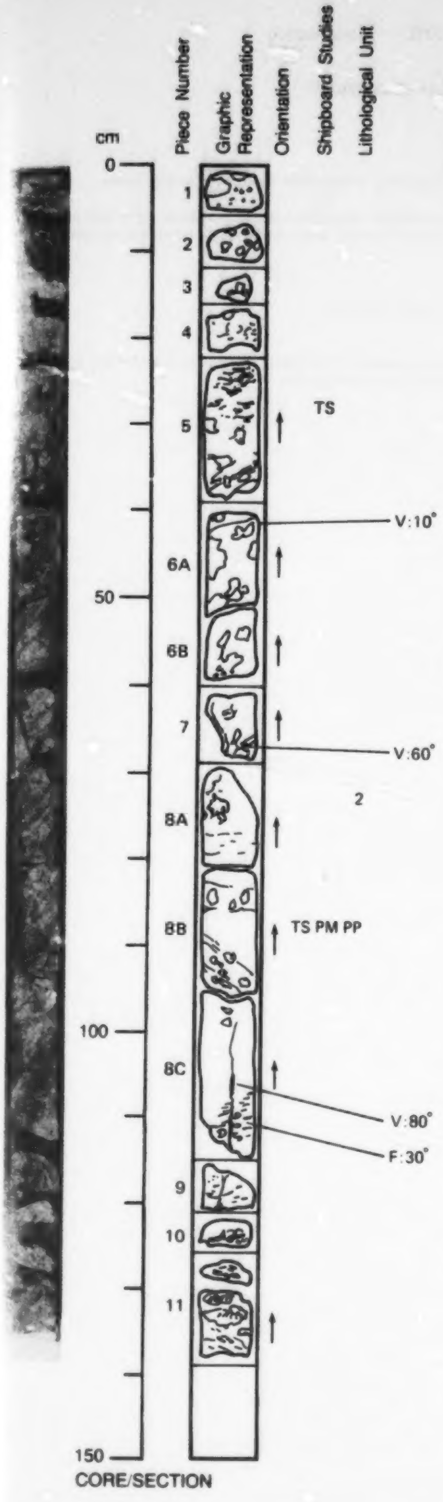
**Olivine Gabbro**

**Pieces 1-8B**

**COLOR:** Gray.
**LAYERING:** None, though olivine is distributed in irregular intervals at 24-27, 34-40, 48-50, 76-81, 112-114, and 139-148 cm.
**DEFORMATION:** Porphyroclastic to well-foliated gabbro in Pieces 1, 2, and top of 3. Bottom of Piece 2 and top of Piece 3 has amphibole-rich zone with ilmenite concentrations and common pyrite. Rest of core is not foliated and has only some sugary, granulated large plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 2-20 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Some granulation.

Clinopyroxene—Mode: 20%-40%.
Crystal size: 2-28 mm.
Crystal shape: Anhedral, well-developed oikocrysts, up to 7 cm enclosing euhedral to subhedral plagioclase.
Preferred orientation: Not determined.
Percent replacement: Some amphibole replacement.

Olivine—Mode: 5%-10%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral, slightly elongate.
Preferred orientation: Not determined.
Percent replacement: Serpentine alteration common; talc pseudomorph at 51 cm.
**SECONDARY MINERALOGY:**
Total percent: 5%-15%.
Texture: Amphibole developed along veins and fractures (dark blue green amphibole).
Percent vein material: Not determined.
Vein material: One large vein of soft white green mineral cutting Pieces 8A and 8B, 2-mm-wide. Same material as that coating fractures in Core 117-735B-26R.
**COMMENTS:** Gradational grain-size changes are again common in the gabbro. It is particularly coarse-grained in Pieces 4B and 8A.



**118-735B-27R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-11

### Weakly Foliated Metagabbro

### Piece 1-5 (top), and 8C (bottom)-11

**COLOR:** Grayish green-light gray.
**LAYERING:** Not apparent except for vague size layering.
**DEFORMATION:** Weak foliation is present.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 0.3 cm.
Crystal shape: Euhedral.
Preferred orientation: Not clear.
Percent replacement: Not determined.

Clinopyroxene—Mode: 60%.
Crystal size: 1-0.3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not clear.
Percent replacement: Almost 100% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 55%.
Texture: Clinopyroxene is almost perfectly replaced by amphibole; plagioclase is altered to albite + prehnite.
Percent vein material: Trace.
Vein material: Amphibole in Piece 2.
**COMMENTS:** Piece 11 is deformed and foliated.

### Olivine-Bearing Metagabbro

### Piece 5 (bottom)-8C (top)

**COLOR:** Gray, partly greenish.
**LAYERING:** Olivine-rich zone (Pieces 8B and 5-6A) defines layering. The zone is 1 to 2.5 cm thick.
**DEFORMATION:** Weak deformation near amphibole + plagioclase veins (Pieces 7 and 6A)
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None—not clear.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-60%.
Crystal size: 2-4 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%-10% by amphibole.

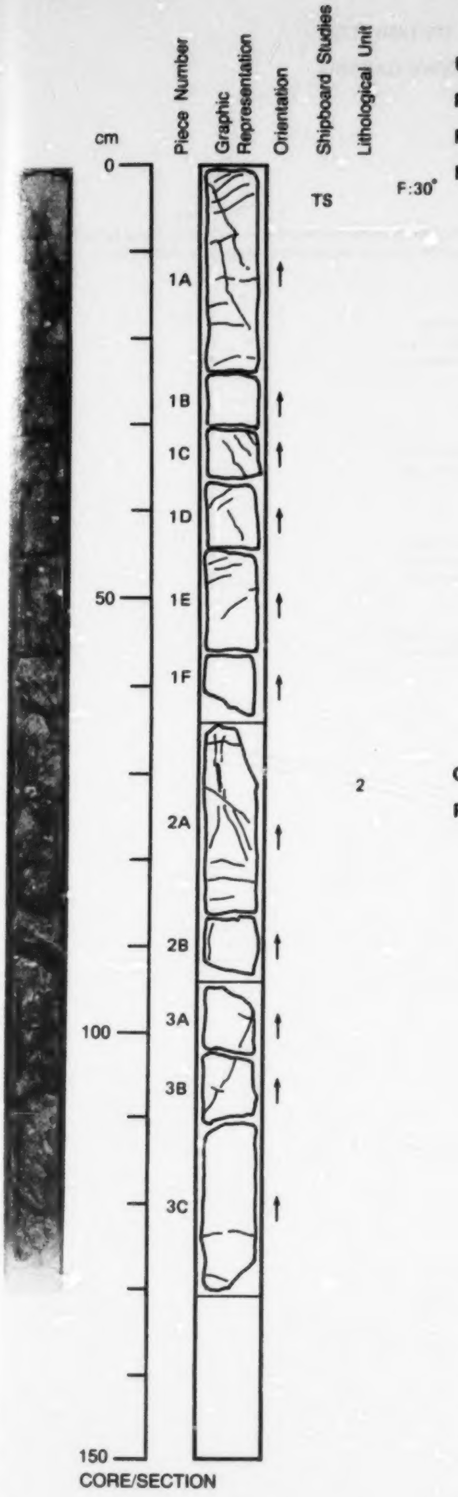
Olivine—Mode: 20%-25%, variable.
Crystal size: 1-3 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Slightly replaced by tremolite + talc or mica.
**SECONDARY MINERALOGY:**
Total percent: 10%-15%.
Texture: Not determined.
Percent vein material: Not determined.
Vein material: Albite in Piece 6A, 7 to 3 mm thick, inclined at 10°.
Amphibole in Pieces 8C and 7, 0.5-5 mm thick, inclined at 60°-80°.

**118-735B-27R-1 (continued)**

## METAMORPHOSED IRON-TITANIUM OXIDE GABBRO

### Piece 5 (top) and 8C (bottom)

**COLOR:** Greenish gray, with a black part.
**LAYERING:** Opaque-rich zones are 2 to 3 cm thick. These zones could be magnetic layers.
**DEFORMATION:** Almost no deformation.
**PRIMARY MINERALOGY:** Similar to olivine-bearing metagabbro (see above), except that opaque mineral content is up to 10%; no olivine was observed. Grain size is smaller than the olivine-bearing metagabbro.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Clinopyroxene is replaced by amphibole.
Percent vein material: None.
Vein material: None.
**COMMENTS:** Iron-titanium oxide gabbros are present in between coarse-grained olivine gabbro and weakly foliated medium- to coarse-grained metagabbro.



**118-735B-27R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-3C

### Foliated Olivine-Bearing Gabbro

### Pieces 1A-1D

**COLOR:** Medium greenish-gray.
**LAYERING:** None.
**DEFORMATION:** Stretching of plagioclase and clinopyroxene crystals is intense and is accompanied by amphibolitization in the upper part of Piece 1A.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Up to 50% by amphibole.

Olivine—Mode: 3%-5%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECOND MINERALOGY:**
Total percent: Slight to moderate alteration.
Texture: Intense amphibole replacement of clinopyroxene (up to 50%) in upper portion of Piece 1A.
Percent vein material: Not determined.
Vein material: Green amphibole containing veins.
Veinlets with sulfides.
**COMMENTS:** Sulfide dissemination throughout the rock.

### Olivine-Bearing Gabbro

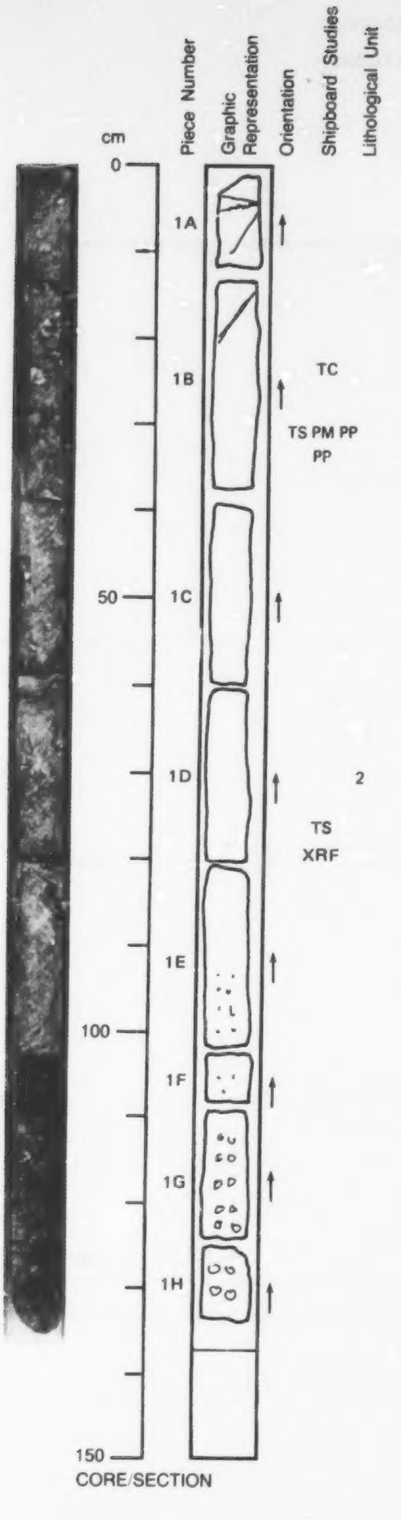
### Pieces 1E-3C

**COLOR:** Medium gray, greenish staining along amphibole-bearing veins.
**LAYERING:** None apparent. However, small decrease in grain size from top to bottom of section.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene: Mode: 35%-40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 3%-5%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Green amphibole veins around clinopyroxene (< 10%). Olivine appears to be relatively fresh. Percent vein material: Not determined.
Vein material: Amphibole veins, especially in Piece 2A. Sulfides in veinlets and disseminated throughout rock.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
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1A
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1C
1D
1E
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1H
TC
TS PM PP
PP
2
TS
XRF
CORE/SECTION

118-735B-27R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1H**

**Olivine-Bearing Gabbro**

**Pieces 1A-1H**

**COLOR:** Greenish gray.
**LAYERING:** Size grading of clinopyroxene, increasing downward from bottom of Piece 1E to Piece 1H.
**DEFORMATION:** Weakly foliated. Localized zones of recrystallized plagiclase (Piece 1H).
**PRIMARY MINERALOGY:**

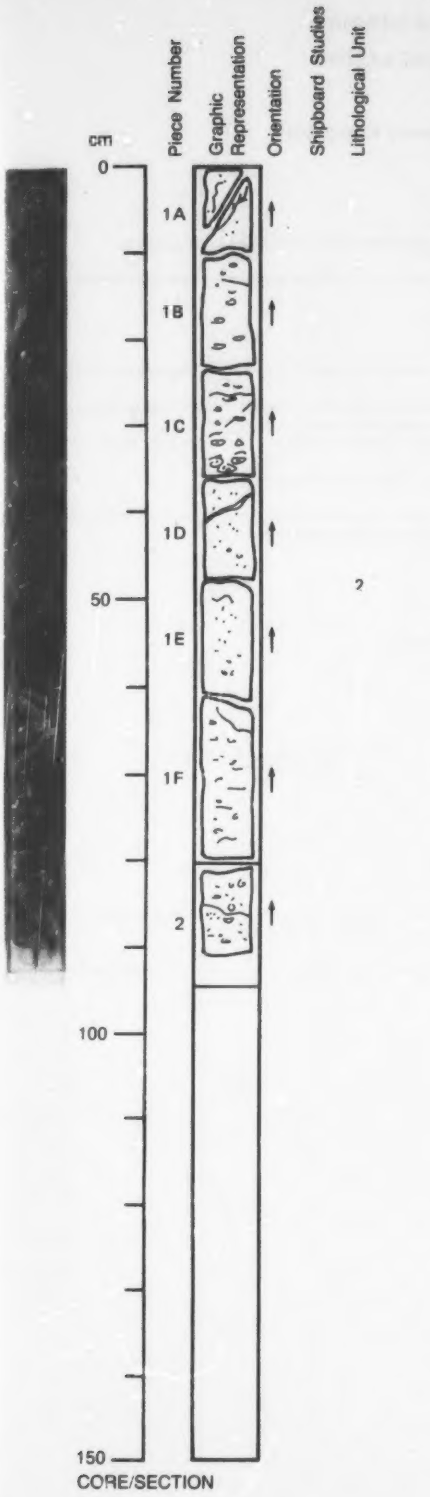
Plagioclase—Mode: 65%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 2-25 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral, interstitial.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 10%-15%.
Texture: Amphibole replacing clinopyroxene.
Percent vein material: Not determined.
Vein material: Amphibole.


cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1A
1B
1C
1D
1E
1F
2
2
CORE/SECTION

**118-735B-27R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-2**

### Massive Olivine-Bearing Gabbro

**Pieces 1A-2**

**COLOR:** Medium gray.

**LAYERING:** Grain-size gradation and phase layering. Two "Grain-size units" can be distinguished: Unit 1 from 0-37 cm (clinopyroxene grain size increases from 0.8 to 3 cm); Unit 2 from 37-92 cm (size of clinopyroxene increases from 0.5 to 2 cm). In Unit 1, phase layering is also apparent: olivine gets enriched toward bottom of Piece 1C.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

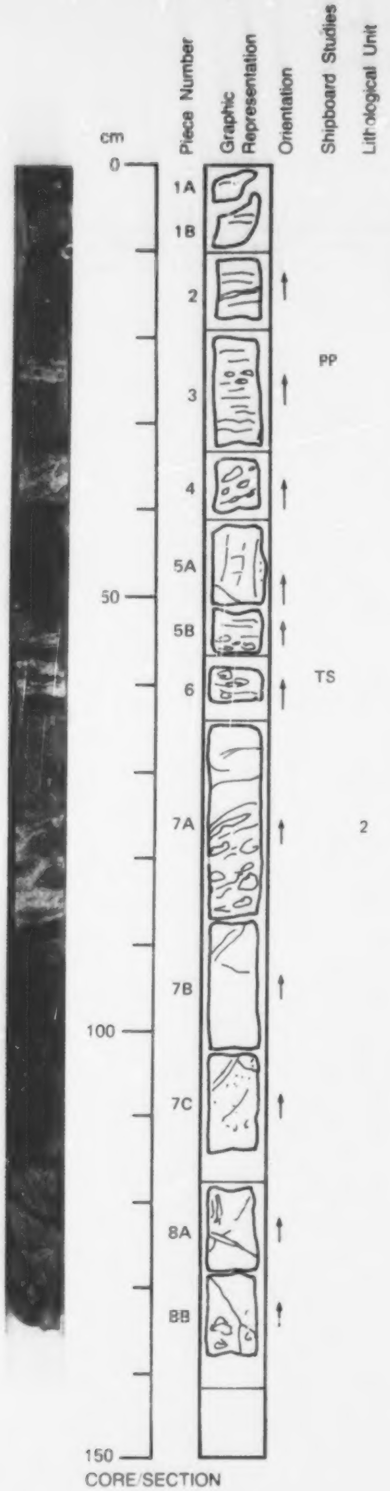
Plagioclase—Mode: 55%-65%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: <2% to 10%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight alteration.
Texture: Olivine is almost completely preserved.
Clinopyroxene is replaced by amphibole subordinately (<5%). Few sulfides.
Percent vein material: Not determined.
Vein material: Amphibole.



### 118-735B-28R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-8B

### Foliated to Porphyroclastic Olivine-Bearing Metagabbro

### Pieces 1A-8B

**COLOR:** Medium gray to greenish gray.
**LAYERING:** No apparent igneous layering.
**DEFORMATION:** Type and intensity of deformation highly variable throughout section.
Pieces 1-3: Strongly foliated.
Piece 2: Contains a porphyroclastic, augen gneissic band about 3 cm wide. Deformation plan is subhorizontal.
Piece 3: Contains mylonitic band.
Piece 4: Porphyroclastic.
Piece 5A: Only weakly foliated.
Piece 5B: Strongly foliated and grades into a oorphyroclastic, augen gneissic zone that is als developed in Piece 6.
Upper one-half of Piece 7A: Weakly foliated, lower one-half strongly foliated with large porphyroclastic clinopyroxene augen (augen gneissic), up to 3 cm.
Pieces 7B and 7C: Feebly foliated, downward decrease in grain size from about 1.5 to <0.5 cm.
Pieces 8A and 8B: Coarse-grained, porphyroclastic, brecciated.

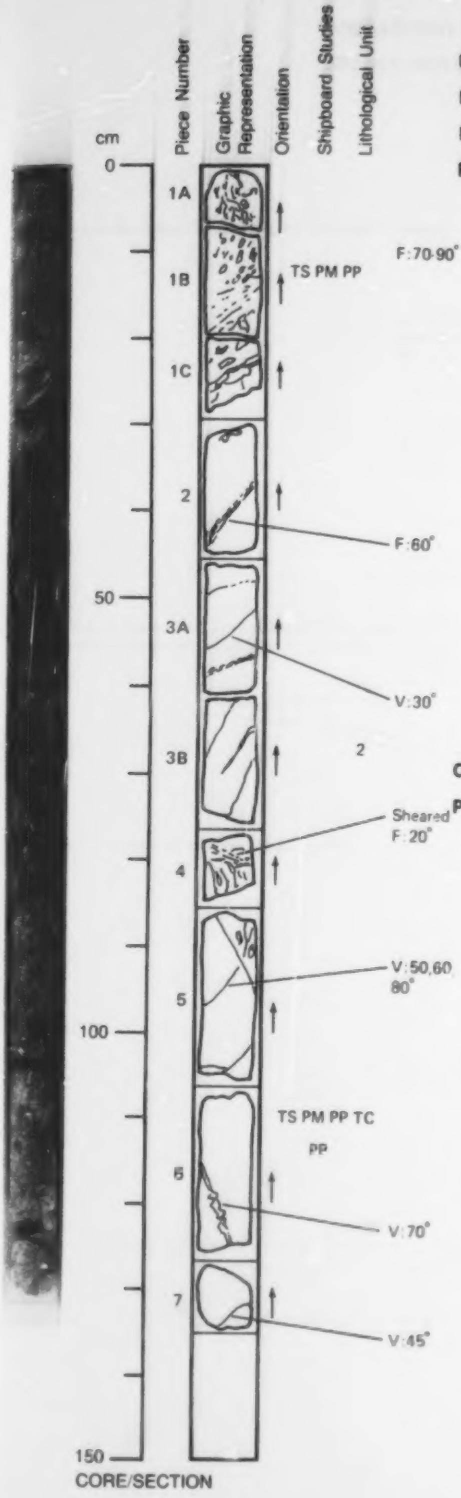
**PRIMARY MINERALOGY:**
Proportions of major phases difficult to estimate. Overall composition about 55% plagioclase 43% clinopyroxene, 2% olivine. Olivine enrichment in Piece 2.

Plagioclase—Mode: 55%.
Crystal size: Up to 10 mm.
Crystal shape: Not determined.
Preferred orientation: Stretched.
Percent replacement: Not determined.

Clinopyroxene—Mode: 43%.
Crystal size: Up to 20 mm.
Crystal shape: Not determined.
Preferred orientation: Stretched.
Percent replacement: Up to 25% by green amphibole.

Olivine—Mode: 2%.
Crystal size: Up to 10 mm.
Crystal shape: Not determined.
Preferred orientation: Stretched
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total Percent: Not determined.
Texture: Green amphibole replacing clinopyroxene (up to 25%). Albite plus amphibole replacement in augen gneissic bands. Disseminated sulfides.
Percent vein material: Not determined.
Vein material: Amphibole. Some veinlets with white mineral filling and some with sulfide.



## 118-735B-28R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-7

### Foliated Olivine-Bearing Metagabbro

### Pieces 1A-2

**COLOR:** Greenish dark gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by elongate amphibole and clinopyroxene (mostly replaced by amphibole) grains. Pieces 1B and 2: Fine-grained, well-foliated amphibolitic zones are present that dip at 60°-70° to 90°. No layering except for amphibolitic bands.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 10 mm.
Crystal shape: Euhedral.
Preferred orientation: Partly elongate parallel to foliation.
Percent replacement: Trace or none.

Clinopyroxene—Mode: 35%.
Crystal size: 5-20 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: Partly elongate parallel to foliation.
Percent replacement: 20% by amphibole.

Olivine—Mode 2%-6%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 2% by tremolite + mica or talc.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Clinopyroxene is replaced by amphibole along rims and cracks.
Olivine is replaced by tremolite + mica or talc.
Amphibole is more abundant in Pieces 1A and 1B, than in Pieces 1C and 2.
Percent vein material: Trace.
Vein material: Amphibole.

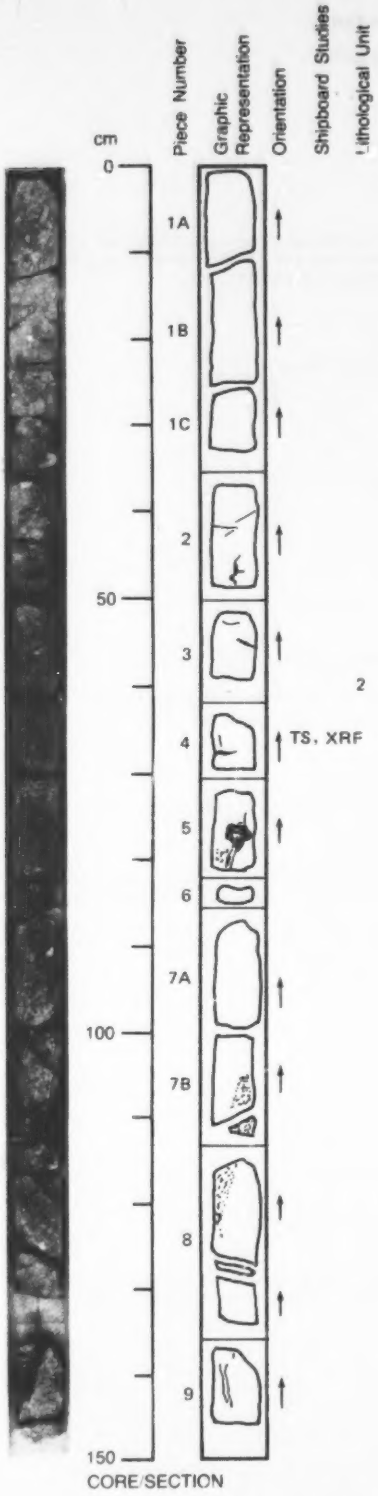
### Olivine Gabbro

### Pieces 4-7

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Feeble, except in Piece 4, where plagioclase-rich sheared zone is present (similar to augen gneissic part of Section 118-735B-28R-1) and in Piece 7, which is slightly cataclastic.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 3-10 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Trace or none.

Clinopyroxene—Mode: 35%.
Crystal size: 3-15 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: 20% by amphibole.

Olivine—Mode: 7%.
Crystal size: 5-10 mm.
Crystal shape: Some are euhedral.
Preferred orientation: Not determined.
Percent replacement: 50%-100% by tremolite + mica or talc.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Clinopyroxene is replaced by amphibole, locally extensive where amphibole veins are 1 to 3 mm thick. Serpentine (2-3 vol%) replaces olivine. The rim of olivine is replaced by pale green tremolite + talc(?).
Percent vein material: Abundant.
Vein material: Amphibole.



**118-735B-28R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-9

### Massive Olivine Gabbro

### Pieces 1A-1C, and 7A-9

**COLOR:** Gray.
**LAYERING:** Possible modal layering. Irregular distribution of plagioclase, clinopyroxene, and olivine.
**DEFORMATION:** Undeformed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 2-25 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%.
Crystal size: 2-25 mm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replacing clinopyroxene and filling fractures. Sodic plagioclase filling 1 mm wide veins. Chlorite + amphibole replacing olivine forming well-developed coronas.
Percent vein material: Not determined.
Vein material: Sodic plagioclase and amphibole.
**COMMENTS:** Finer-grained (microgabbro) segments in Pieces 7B and 8.

### Porphyroclastic Metagabbro

### Pieces 2, 3, 5, and 6

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** Weakly foliated. Porphyroclasts of clinopyroxene. Likely recrystallization of clinopyroxene and plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: <1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%
Crystal size: <1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%.
Crystal size: 1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Green amphibole replaces clinopyroxene and fills veins. Opaque-rich zones in Pieces 2 and 5 (20% of Piece 5), often with small amount of sulfide.
Percent vein material: Not determined
Vein material: Amphibole.
**COMMENTS:** Finer-grained interval in Piece 5, cored surface of Piece 3.

## 118-735B-28R-3 (continued)

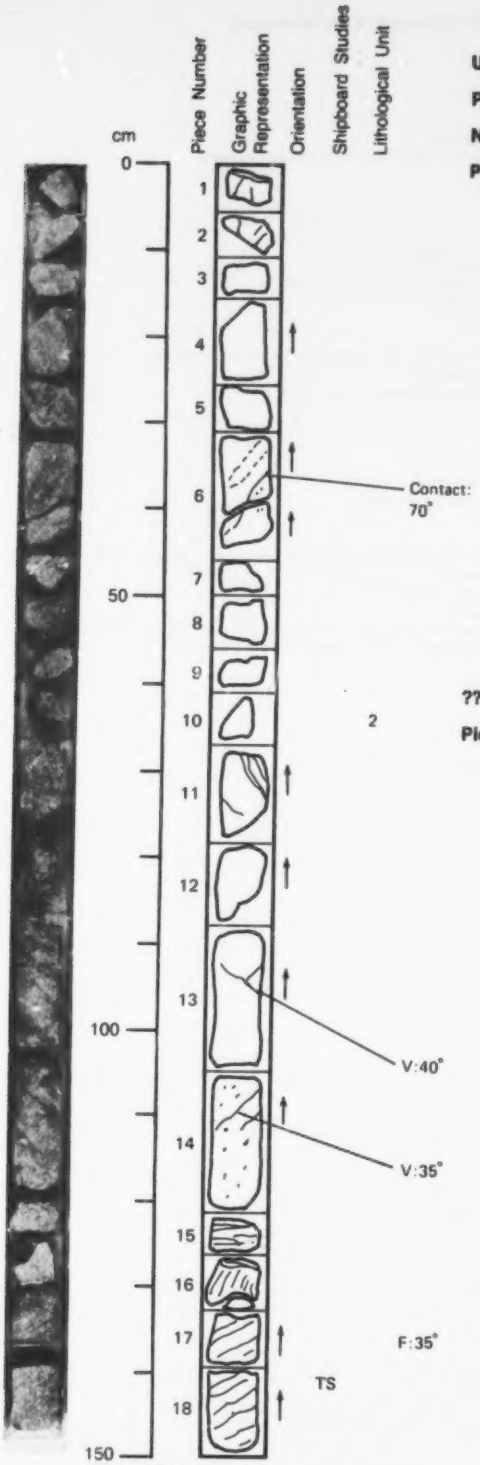
### Norite

### Piece 4 (sawed surface)

**COLOR:** Greenish gray; locally, purplish gray.
**LAYERING:** None apparent, but local concentrations of low-calcium pyroxene.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 70%.
Crystal size: 4-12 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by epidote mineral.
Low calcium pyroxene-Mole: 35%.

Crystal size: 2-15 mm.
Crystal shape: Anhedral to subhedral with herringbone exsolution lamellae.
Preferred orientation: Not determined.
Percent replacement: Coronas of termolite + chlorite + talc.

Clinopyroxene—Mode: 5%.
Crystal size: 5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Orthopyroxene with well-developed coronas of tremolite + chlorite + talc. Plagioclase partly altered to epidote mineral. Clinopyroxene altered to amphibole.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Sharp contact with finer-grained segment on cored surface of Piece 4. Microgabbro composed primarily of plagioclase + clinopyroxene (now amphibole).



**118-735B-28R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-18

### Nonfoliated Metagabbro

### Pieces 1-3

**COLOR:** Greenish-gray.
**LAYERING:** No layering.
**DEFORMATION:** No deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Not determined.
Crystal size: <10 mm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replaced by albite.

Clinopyroxene—Mode: Not determined.
Crystal size: <10 mm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replaced by amphibole.

Olivine—Mode: Not determined.
Crystal size: <10 mm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic.
Percent vein material: <5%.
Vein material: Amphibole.

### ??? Olivine-Bearing Gabbro

### Pieces 4-6A, and 11-14

**COLOR:** Gray.
**LAYERING:** Fine-grained bands in Pieces 6 and 14 (grain size <1 cm); grain size in coarse-grained pieces <3 to 5 cm. Olivine-rich layer dipping at 70° in Piece 6A.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: See layering above.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replaced by albite.

Clinopyroxene—Mode: 40%.
Crystal size: See layering above.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replaced by amphibole.

Olivine—Mode: <2-10%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replaced by amphibole and talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic.
Percent vein material: <1%.
Vein material: Amphibole.

## 118-735B-28R-4 (continued)

**Amphibolitized Gabbro**

**Piece 6B**

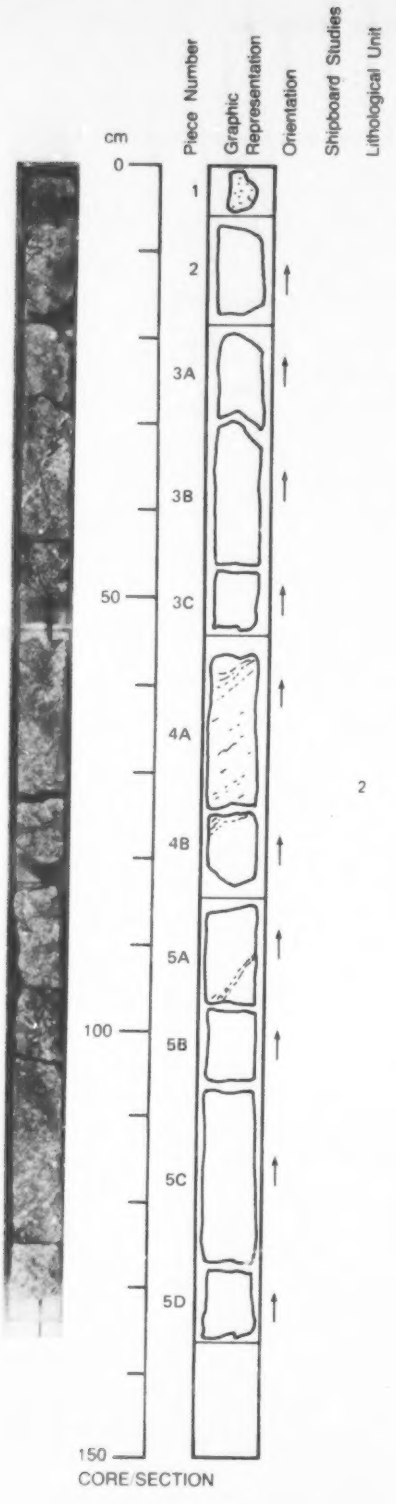
Weakly cataclastic, mineralogy identical to foliated metagabbros (Pieces 7-11 and 15-18).

**Foliated Metagabbro**

**Pieces 7-10, and 15-18**

**COLOR:** Green gray.
**LAYERING:** No layering.
**DEFORMATION:** Foliation dips 35° and lineation defined by aligned amphiboles.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: <10 mm.
Crystal shape: Porphyoclasts flattened in the foliation.
Preferred orientation: Marks foliation.
Percent replacement: 5% by more sodic plagioclase.

Clinopyroxene—Mode: 60%.
Crystal size: <10 mm.
Crystal shape: Porphyroclasts flattened in the foliation.
Preferred orientation: Marks foliation.
Percent replacement: 100% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 50%-100%.
Texture: Pseudomorphic to granoblastic.
Percent vein material: <1%.
Vein material: Amphibole vein in Pieces 15 and 16.



**118-735B-29R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-5D

### Amphibolitized Metagabbro

### Pieces 1 and 2

**COLOR:** Gray.
**LAYERING:** Not determined.
**DEFORMATION:** Weakly foliated.
**PRIMARY MINERALOGY:** Similar to brecciated metagabbro described below.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Not determined.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Medium-grained metagabbro consisting of pale green amphibole and milky white plagioclase (albitized) and minor interstitial ilmenite.

### Brecciated Metagabbro

### Pieces 2-3C

**COLOR:** Not determined.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Not determined.
Crystal size: 3 mm to greater than 1 cm.
Crystal shape: Subhedral granular.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: Not determined.
Crystal size: 3 mm to greater than 1 cm.
Crystal shape: Subhedral to intergranular, locally oikocrystic, often broken into angular fragments 3 mm to more than 1 cm wide.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: Not determined.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% by clay minerals(?).
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Not determined.
Percent vein material: Not determined.
Vein material: Amphibolite ± plagioclase.
**COMMENTS:** Coarse- to very coarse-grained subhedral granular gabbro with occasional oikocrysts of clinopyroxene enclosing subhedral plagioclase laths crisscrossed by a network of amphibole and amphibole-plagioclase veins. Pyroxenes generally appear fragmented into coarse to very coarse angular feldspar. Many of the pyroxene clasts appear rotated. The matrix consists of both recrystallized primary feldspar and hydrothermal plagioclase and amphibole. Rare clay-filled anhedral grains could be olivine pseudomorphs.

## 118-735B-29R-1 (continued)

### Amphibolitized Metagabbro Gneiss

### Pieces 4A and 4B

**COLOR:** Green to greenish gray.
**LAYERING:** Not determined.
**DEFORMATION:** Medium-grained gneissic texture with occasional coarse pyroxene augen.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Not determined.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: Not determined.
Crystal size: 1-3 mm, a few have coarser augen.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: 90%-100% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole and plagioclase (milky). Lower half of zone contains paler green amphibole and abundant ilmenite (5%-10% locally). A few rare coarse pyroxene augen are present that appear amphibolitized in hand sample.
Percent vein material: 5%-10%.
Vein material: Amphibole and plagioclase.

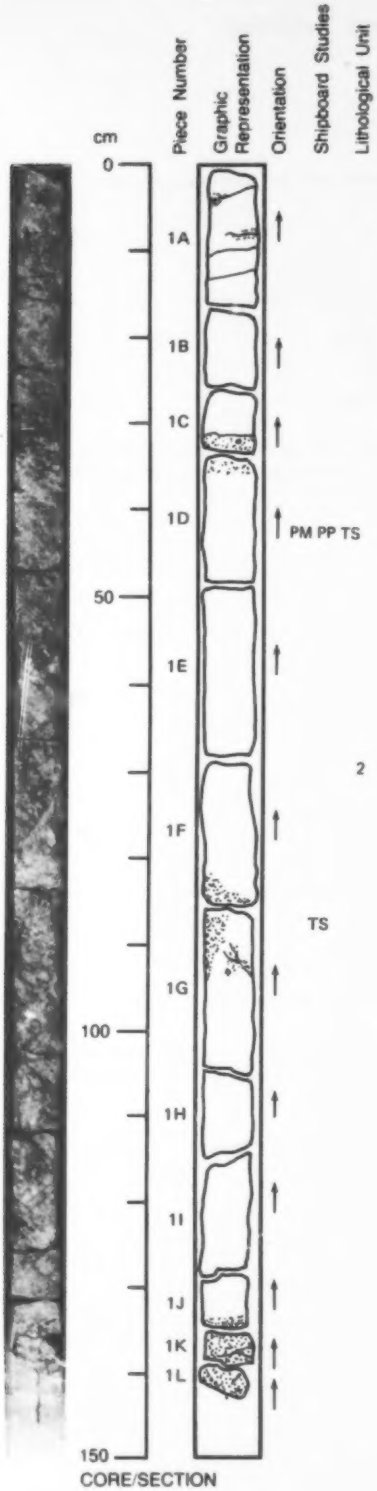
### Olivine-Bearing Gabbro

### Pieces 4B-5D

**COLOR:** Greenish gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Gneissic band cutting gabbro at 45° at 91-99 cm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 0.5-1.5 cm in clinopyroxene oikocrysts, >1 cm elsewhere.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: Replaced by albite.

Clinopyroxene—Mode: 40%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral intergranular.
Preferred orientation: None.
Percent replacement: Locally replaced and rimmed by amphibole.

Olivine—Mode: <1%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100%. Replacement mineral not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene locally rimmed and replaced by amphibole; plagioclase locally altered to milky white mineral (albitized), particularly around a small gneissic band cutting gabbro at 45° at 91-99 cm. Patches of ilmenite locally present.
Percent vein material: None.
Vein material: None.
**COMMENTS:** Coarse-grained anhedral to subhedral granular, with occasional clinopyroxene oikocrysts enclosing 0.5- to 1.5-cm plagioclase laths.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Piece Number
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2
CORE/SECTION

**118-735B-29R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1L**

### Massive Olivine Gabbro

**Pieces 1A-1L**

**COLOR:** Variable white to gray; dominantly gray.
**LAYERING:** None.
**DEFORMATION:** Only that associated with veining.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%.
Crystal size: 3-20 mm; augen 10 mm.
Crystal shape: Andedral to subhedral.
Preferred orientation: None.
Percent replacement: 15%-30% by sodic plagioclase.

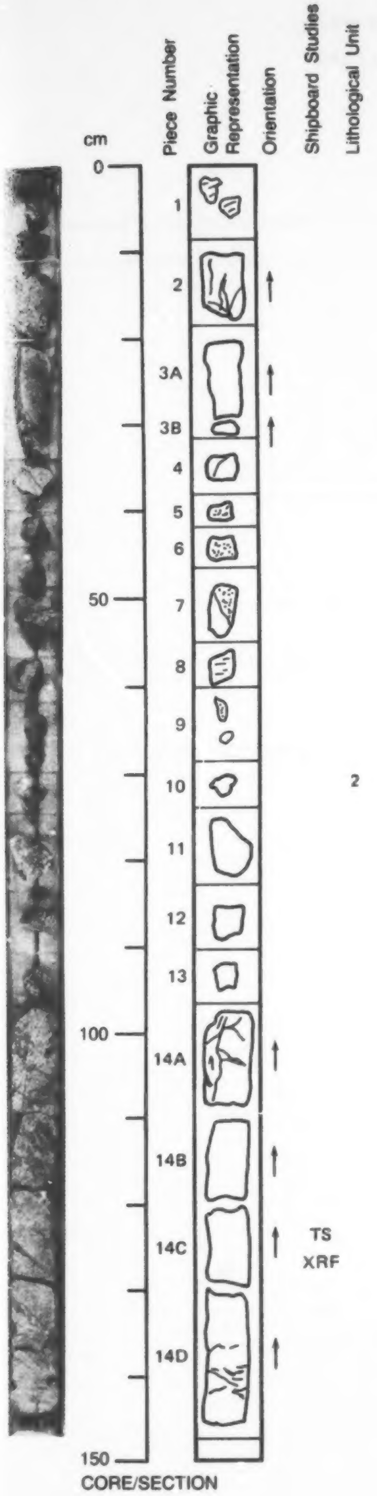
Clinopyroxene—Mode: 40%.
Crystal size: 3-40 mm; augen 10 mm; large clinopyroxene oikocryst (4-5 cm wide) in Piece 1E at 55-60 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 25%-75% by amphibole.

Olivine—Mode: 0%-5%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20%-100% by talc and smectite.

**SECONDARY MINERALOGY:**

Total percent: 25%-100%.
Texture: Amount of alteration varies over length of section from 25%-100%. Alteration is greatest at 5-15, 29-39, 80-94, and 130-142 cm. In these intervals, intense replacement of clinopyroxene by amphibole and of plagioclase by albite occurs. Lower in the section, olivine is replaced by talc and smectite. Secondary ilmenite (10 modal%) is concentrated into layers and around clinopyroxene from 0-32 cm. Trace of sulfides in Piece 1B.
Percent vein material: 1%-2%.
Vein material: Green amphibole. Veins are very thin.

### 118-735B-29R-3



## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-14D

### Amphibolitized Gabbro

### Pieces 1, 2, and 4-11

**COLOR:** Green-white to green.
**LAYERING:** No layering.
**DEFORMATION:** Degree of foliation varies.
Piece 1: A strong foliation defined by aligned amphiboles.
Piece 8: A more weakly defined foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Only some plagioclase left.
Original mineralogy probably like that in olivine gabbro below.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive albitization.

Clinopyroxene—Mode: Not determined.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Nearly 100% by amphibole.

Olivine—Mode: 10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% by amphibole, clay(?), and calcite(?).
**SECONDARY MINERALOGY:**
Total percent: Up to 100% in some pieces.
Texture: Dark green amphibole after clinopyroxene, which also fills veins and fractures. Some albitization of plagioclase. No opaque zones in this interval.
Percent vein material: Minor.
Vein material: Amphibole.
**COMMENTS:** Pieces 5-7 are fine-grained; Piece 7 has a contact between coarse and fine amphibolite that may record an igneous grain-size contrast.

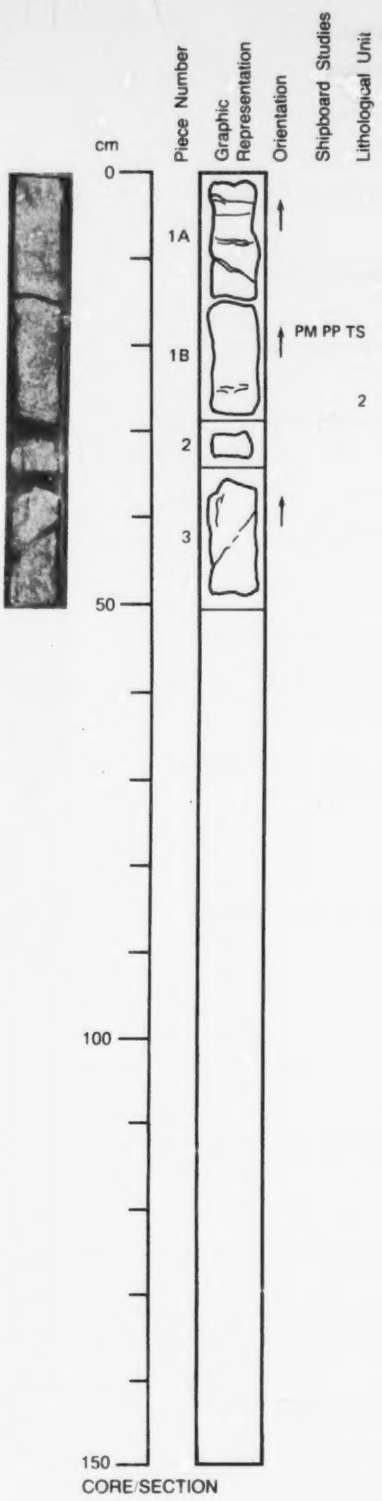
### Olivine Gabbro

### Pieces 3 and 12-14D

**COLOR:** Gray.
**LAYERING:** No layering. Medium- to coarse-grained (2-10 mm) throughout.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 3-10 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 2-11 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive replacement by amphibole along veins and fractures.

Olivine—Mode: 2%-4%.
Crystal size: Sporadically developed.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Almost completely replaced by clay minerals and serpentine.
**SECONDARY MINERALOGY:**
Total percent: 10%-30%.
Texture: Most olivine partially altered to clay minerals and serpentine. Extensive amphibolitization along veins and fractures. Left side of Piece 14A and bottom of Piece 14D strongly amphibolitized and little deformed. Granulation of plagioclase and bending of amphibole present.
Percent vein material: 3%.
Vein material: Amphibole. Vein in Piece 14A looks like a small vertical offset. Pieces 3-8: Veined with a black alteration phase. 1-3 mm wide.



**118-735B-29R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-3**

**Amphibolitized Olivine Gabbro**

**Pieces 1A-3**

**COLOR:** Gray to greenish-white.

**LAYERING:** Grain-size variations, parallel to a very faint subhorizontal foliation, probably magmatic in origin.

**DEFORMATION:** Small fracture crosscutting Piece 3. May be a little offset; deformation along amphibolitized zones at 6-12 cm.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-60%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: Weak igneous lamination.
Percent replacement: Some albitization and plagioclase granulation.

Clinopyroxene—Mode: 20%-40%.
Crystal size: 2-11 mm.
Crystal shape: Anhedral.
Preferred orientation: Igneous lamination weakly developed.
Percent replacement: Extensively replaced by green amphibole.

Olivine—Mode: 5%.
Crystal size: 3-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 80%-100% by clay minerals and serpentine.

**SECONDARY MINERALOGY:**

Total percent: 40%-60%.
Texture: Green amphibole after clinopyroxene. Some plagioclase granulation. A whitish slightly albitized zone at 25 cm. Amphibolitization in this section is largely static. No prominent foliation.
Percent vein material: Not determined.
Vein material: Not determined.

**COMMENTS:** 0-5 and 45-50 cm, moderately fresh, medium-grained olivine gabbro as in Section 118-735B-29R-3.

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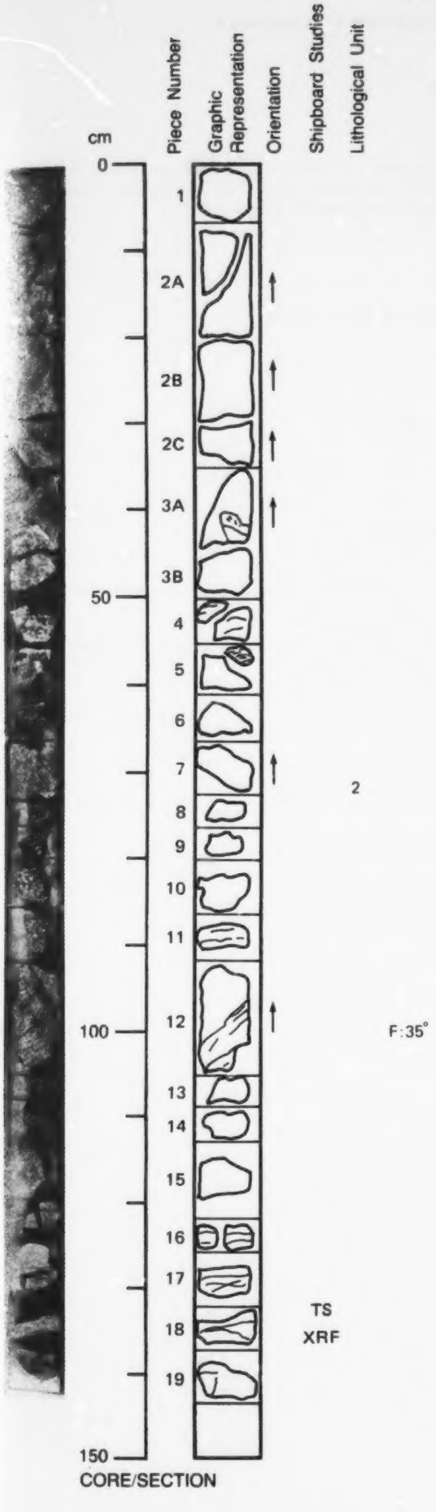


**118-735B-30R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-19**

### Massive Olivine Gabbro

**Pieces 1-3, 5, and 16**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Absent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 1-6 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: 1%.

Clinopyroxene—Mode: 41%.
Crystal size: 1-5 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 50% by green amphibole.

Olivine—Mode: 4%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100%, replacement; mineral undetermined.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Green amphibole replaces clinopyroxene.
Percent vein material: <5%.
Vein material: Piece 2A: Veins filled with green amphibole and traces of plagioclase. Piece 3A: Plagioclase-rich vein (3 mm thick).

### Porphyroclastic Metagabbro

**Pieces 4 and 8-10**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Foliation defined by flattening of plagioclase and clinopyroxene. Large porphyroclasts of pyroxene are fractionated and granulated.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-10 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: Not determined.

Clinopyroxene—Mode: 37%-39%.
Crystal size: 2-12 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: Not determined.

Ilmenite—Mode: 1%-3%.
Crystal size: 3 mm.
Crystal shape: Granular.
Preferred orientation: Yes.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Green amphibole pseudomorphs after clinopyroxene. Plagioclase granoblasts derived from primary plagioclase. Ilmenite is probably partly transformed into magnetite.
Percent vein material: Not determined.
Vein material: Not determined.

## 118-735B-30R-1 (continued)

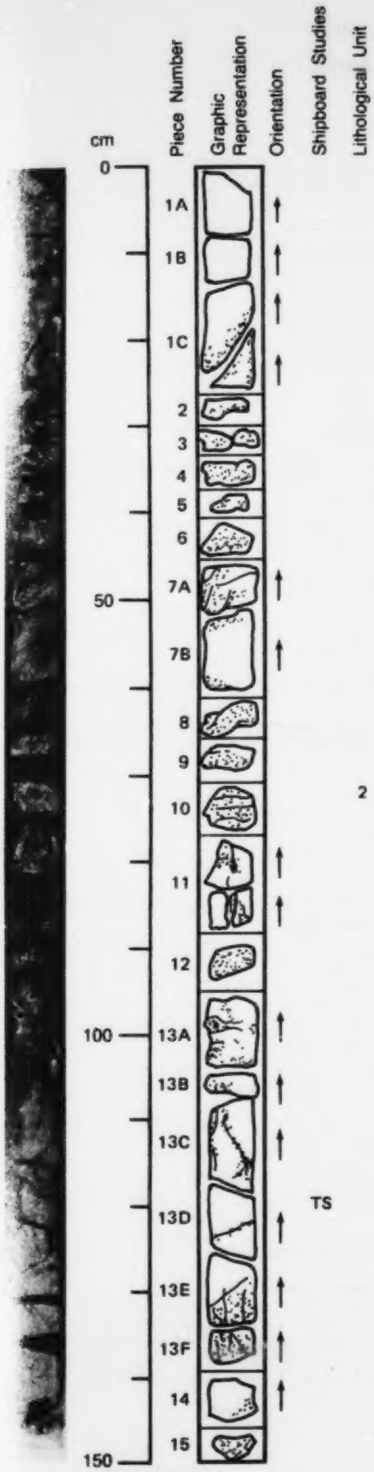
### Foliated Metagabbro

### Pieces 7 and 11-19

**COLOR:** Dark green.
**LAYERING:** None.
**DEFORMATION:** Foliation is defined by preferred orientation of pyroxene (now amphibole) and plagioclase that is recrystallized into fine bands parallel to the foliation plane. In Piece 12, a small fault parallel to the foliation is more intensely amphibolitized.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-3 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: 50% by undetermined mineral.

Clinopyroxene—Mode: 35%.
Crystal size: 2-4 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: 100% by amphibole.

Orthopyroxene—Mode: 5%.
Crystal size: 2-3 mm.
Crystal shape: Lens.
Preferred orientation: Yes.
Percent replacement: 100% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 90%.
Texture: Green amphibole replaces almost all the clinopyroxene and orthopyroxene(?) (brown oxidized core).
Percent vein material: <5%.
Vein material: Veins of amphibole cut the foliation; the wall-rock is more intensively altered in their vicinity. Slickensides are present in the plane of veining. Chlorite can be present in association with green amphibole.



CORE/SECTION

### 118-735B-30R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-15**

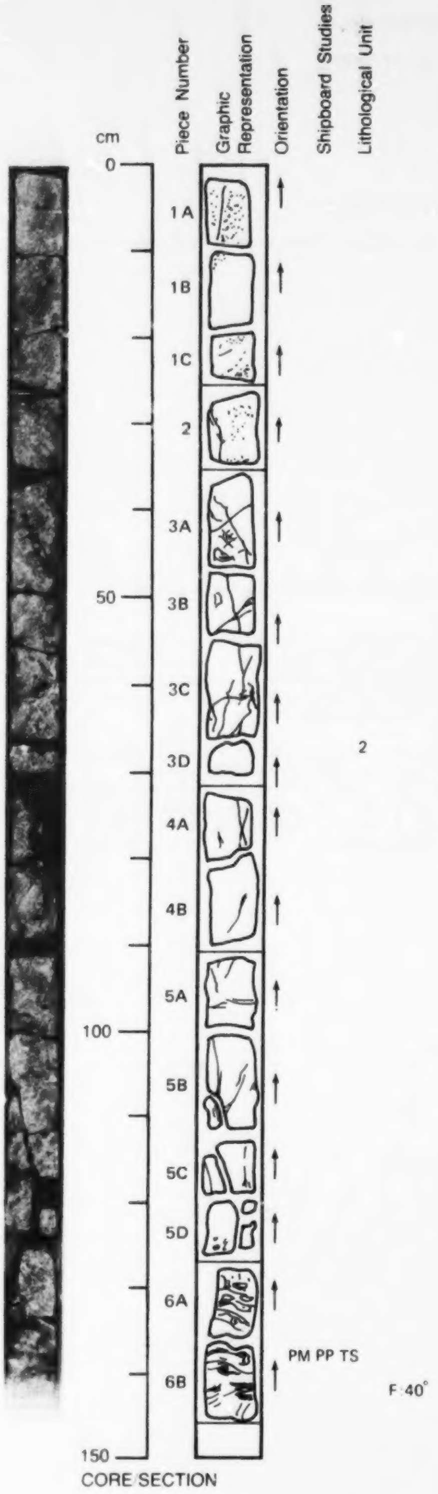
**Olivine Gabbro**

**Pieces 1A-15**

**COLOR:** Dark gray, mottled gray-white near altered zones.
**LAYERING:** None.
**DEFORMATION:** Brecciation/granulation of plagioclase in larger amphibole and albite veins—no foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2 mm-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50% by albite(?).

Clinopyroxene—Mode: 40%.
Crystal size: 2 mm-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 75% by amphibole.

Olivine—Mode: 0%-10%.
Crystal size: 4 mm-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 95% by black mineral and green-white fibrous mineral.
**SECONDARY MINERALOGY:**
Total percent: 50%-65%.
Texture: Olivine altered to a black mineral that forms a network around olivine grains. This network is often seen with void spaces between where olivine is absent. Piece 13E: these spaces filled by talc. Clinopyroxene 50%-100% altered to green amphibole. Plagioclase altered to whiter feldspar—possibly albite, but may be just granulated calcic plagioclase. Olivine often surrounded by halo of green and white fibrous minerals.
Percent vein material: Not determined.
Vein material: Chlorite, amphibole, and sodic plagioclase. Fractures filled/coated by chlorite and amphibole (?). Some filled by white minerals probably sodic plagioclase.
**COMMENTS:** Modal abundances vary over length of section. Olivine abundant at 0-26, 120-145 cm, and in Piece 10. Other intervals are void of olivine. Grain size is also variable. Predominant grain size coarse, but finer units in Pieces 5, 7A and 7B, and from 105-120 cm. These may be either intrusive, or represent areas of recrystallization.



## 118-735B-30R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-6B

### Altered Olivine-Bearing Gabbro

### Pieces 1-3B

**COLOR:** Gray.
**LAYERING:** One coarse to fine gradation.
**DEFORMATION:** Some fractures or shears in Pieces 3A and 3B.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-70%.
Crystal size: 1-12 mm.
Crystal shape: Euhedral (in clinopyroxene) to anhedral.
Preferred orientation: Not determined.
Percent replacement: Various, amphibole after clinopyroxene.

Clinopyroxene—Mode: 30%-60%.
Crystal size: 1-18 mm, in plagioclase up to 35 mm.
Crystal shape: Anhedral, enclosing plagioclase.
Preferred orientation: Not determined.
Percent replacement: Increases from Piece 1A to Piece 3B, replaced by amphibole.

Olivine—Mode: 0%-2%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Commonly with talc/tremolite rims.
**SECONDARY MINERALOGY:**
Total percent: 5%-70%.
Texture: Green amphibole after clinopyroxene.
Amphibolization increases downcore to Piece 3B.
Percent vein material: 3%-4%.
Vein material: Crosscutting fractures and shear zones with extensvie amphibole development along them.
**COMMENTS:** Similar to Section 118-735B-30R-5 material. Very coarse-grained, crystals up to 3.5 cm at 50 cm, grading to a fine-grained interval at 30 cm. Upper part of section is fine- to medium-grained.

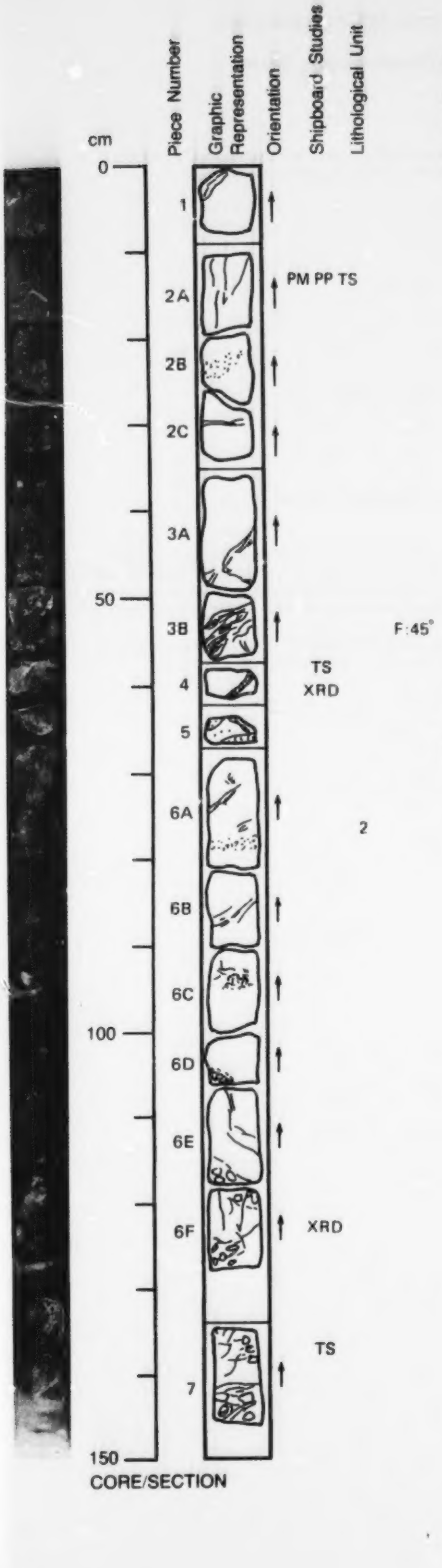
### Variously Amphibolitized Olivine-Bearing Gabbro

### Pieces 3C-6B

**COLOR:** Gray-green.
**LAYERING:** None.
**DEFORMATION:** Slight elongation of pyroxene and olivine in places. Some granulation of plagioclase. Numerous veins, usually with amphibole development.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 30%-70%.
Crystal size: 2-20 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-60%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral, poikilitic.
Preferred orientation: None.
Percent replacement: Various by amphibole.

Olivine—Mode: 0%-8% in sporadic intervals.
Crystal size: Up to 20 mm in olivine-rich interval (95-101 cm).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Variously altered to talc and tremolite.
**SECONDARY MINERALOGY:**
Total percent: Slight to extensive in different parts of the core.
Texture: Abundant actinolitic amphibole. Piece 3D: euhedral, fibrous actinolite (up to 3 mm long) and talc growing in a shallow cavity on back of sample. Several shallow cavities in other pieces. Piece 6A: opaque-rich zone, with a foliation dipping at 40° defined by elongate feldspar zones. Piece 6B: some red (oxidative?) staining between grains and in cleavage of an altered clinopyroxene. Abundant amphibole replacing clinopyroxene, particularly along veins.
Percent vein material: 5%.
Vein material: Amphibole.
**COMMENTS:** Very similar to Section 118-735B-30R-5.



## 118-735B-30R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-7

### Fine- to Medium-Grained Olivine-Bearing Gabbro

### Pieces 1-3A

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Piece 1: sheared white zone. Fine-grained zone at 25 cm. Pieces 2A, 2C, and 3A: amphibole-albite zones. Trace amounts of finely disseminated pyrite throughout.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-70%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5% by undetermined mineral.

Clinopyroxene—Mode: 25%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60%-65% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: < 1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 75%-80% by talc and/or amphibole.
**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Clinopyroxene replaced by green amphibole, and olivine by talc and/or amphibole.
Percent vein material: None.
Vein material: None.

### Porphyroclastic Gabbro

### Piece 3B

**COLOR:** Gray.
**LAYERING:** No primary layering.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: < 1 to 10 mm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate by sodic plagioclase.

Clinopyroxene—Mode: 40%.
Crystal size: 6-8 mm augen. Fine bands of white plagioclase (granulated or albitized) and amphibole.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Extensive.
Texture: Plagioclase and clinopyroxene deformed and replaced by sodic plagioclase and green amphibole, respectively.
Percent vein material: None.
Vein material: None.

## 118-735B-30R-4 (continued)

## Brecciated, Partially Amphibolitized, Olivine-Bearing Gabbro

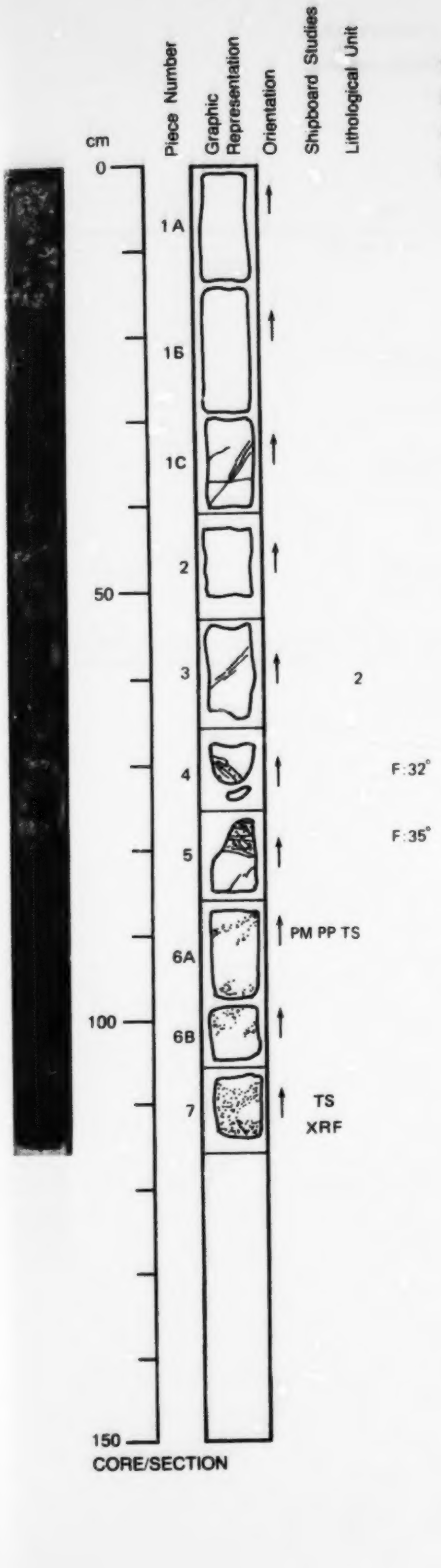
### Pieces 4-7

**COLOR:** Gray to gray and white.
**LAYERING:** No layering. Fine-grained zone at 80 cm. Very coarse-grained at 94 cm.
**DEFORMATION:** Some granulation of feldspar and brecciation near veins.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: 40%-50%.
  Crystal size: 2-20 mm.
  Crystal shape: Euhedral to anhedral.
  Preferred orientation: None.
  Percent replacement: 30% by albite(?).

  Clinopyroxene—Mode: 40%-50%.
  Crystal size: 2-20 mm.
  Crystal shape: Anhedral.
  Preferred orientation: None.
  Percent replacement: 20%-70% by amphibole.

  Olivine—Mode: 0%-3%.
  Crystal size: 2-5 mm.
  Crystal shape: Anhedral.
  Preferred orientation. None.
  Percent replacement: 100% by undetermined mineral.
**SECONDARY MINERALOGY:**
  Total percent: 30%-35%.
  Texture: Freshest at 75-86 and 110-115 cm. 20%-70% amphibole after clinopyroxene, particularly along veins and fractures with vuggy spaces (92 cm). At 104-107, 116-118, 123-134, and 140-145 cm, sample is cut by brecciated zones of pyroxene and granulated plagioclase. There is amphibolitization of clinopyroxene and possibly albitization of plagioclase.
  Vein percent: 30%.
  Vein material: Two large (1-3 mm wide) veins of a very white vein material, probably feldspar. Same material in smaller veins throughout. Veins cut Pieces 4 and 5.

## 118-735B-30R-5



### UNIT 2: OLIVINE-BEARING AND OLIVINE-GABBRO

**Pieces 1-7**

**Olivine-Bearing Gabbro**

**Pieces 1-7**

**COLOR:** Gray.

**LAYERING:** No igneous layering, but coarse to fine transitions.

**DEFORMATION:** Foliation in pieces 4 and 5, defined by stretching of clinopyroxene. Includes a medium-grained zone in piece 4 and a fine-grained zone in piece 5. Plagioclase extensively albitized (very white) in these zones, maybe in part from granulation.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 70%-40%.
Crystal size: 1-12 mm.
Crystal shape: Euhedral (in clinopyroxene) to anhedral. Appears fresh and undeformed, except in shear zones.
Preferred orientation: None.
Percent replacement: Some granulation in shear zones.

Clinopyroxene—Mode: 30%-60%.
Crystal size: 1-18 mm.
Crystal shape: Anhedral. Partially enclosing plagioclase to poikilitic (piece 1B).
Preferred orientation: None.
Percent replacement: Slight to extensive replacement to amphibole along veins and shear zones.

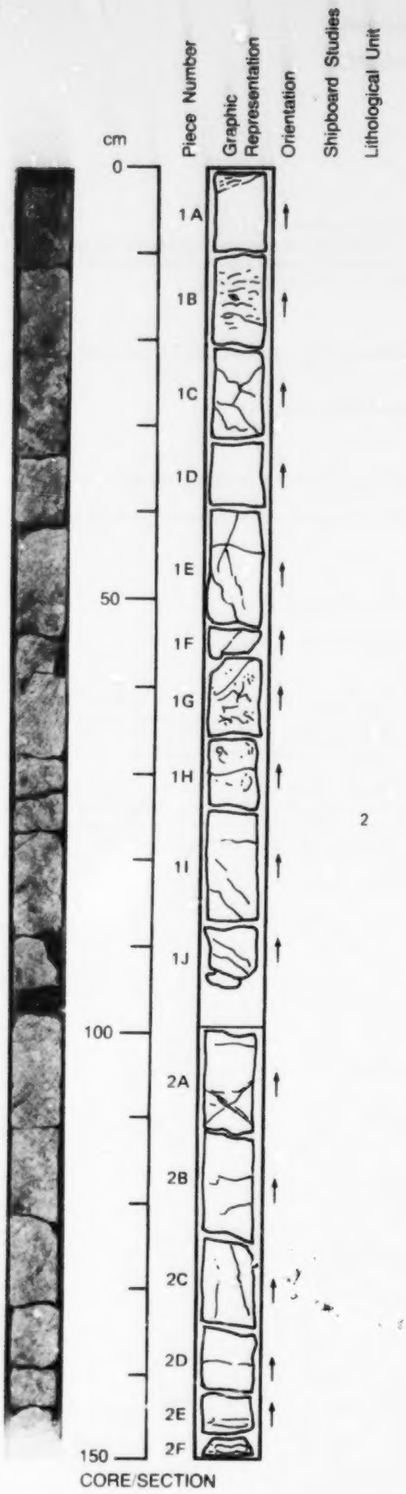
Olivine—Mode: 0%-8%.
Crystal size: 2-10 mm.
Crystal shape: Piece 1A partially encloses plagioclase.
Preferred orientation: None.
Percent replacement: Commonly, light gray talc-tremolite rims.

**SECONDARY MINERALOGY:**

Total percent: 5%-70%.
Texture: Amphibole (dark green after clinopyroxene) most intense in shear zone at 75 cm and in amphibole veins (1-3 mm wide) as at 34 and 60 cm. In shear zone, perhaps some albite after plagioclase. The very white color may be due largely to mechanical diminution of the plagioclase. Percent vein material: Not determined. Vein material: Amphibole.

**COMMENTS:**

There are several of the coarse- to fine-grained transitions in pieces 6 and 7. In piece 7, there is little sign of deformation, and the fine-grained zone is quite irregular. There is fine (<1 mm) to finely disseminated pyrite present in piece 4 through 7. Pyrite occurs in both coarse- and fine-grained sections, although it is a little more common in the fine-grained zones.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1 A
1B
1C
1D
1E
1F
1G
1H
1I
1J
2A
2B
2C
2D
2E
2F
2
CORE/SECTION

118-735B-31R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-2F

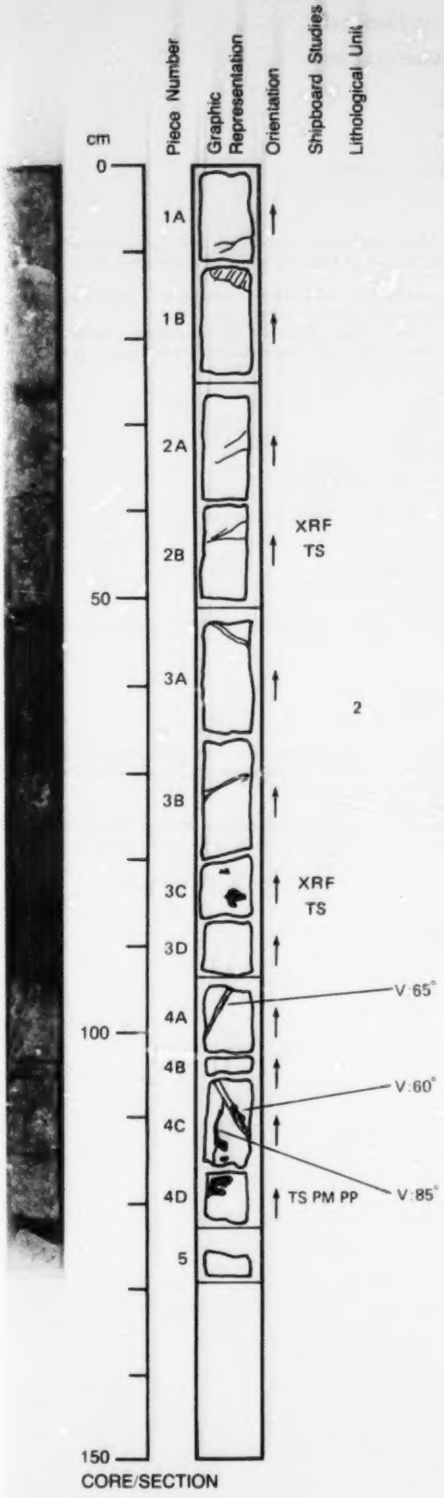
### Olivinr-Bearing Gabbro

### Pieces 1A-2F

**COLOR:** Medium gray. Greenish gray near veins.
**LAYERING:** Vague if at all. Small variations in grain size from coarse-grained (clinopyroxene up to 3 cm) to medium-grained (Pieces 1G, 1H, 1I, and 2B).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 0.4-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 44%-45%.
Crystal size: 0.4-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent alteration: <10% by amphibole.

Olivine—Mode: 0%-2%.
Crystal size: <0.4-2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Green amphibole partially replaces clinopyroxene. Stronger replacement (up to 50%) only at very bottom of section (144-150 cm). Sulfides disseminated throughout most of the section.
Percent vein material: Not determined.
Vein material: Veinlets with amphibole.



### 118-735B-31R-2

## UNIT 2: OLIVINE-BEARING GABBRO AND OLIVINE GABBRO

### Pieces 1A-5A

### Olivine-Bearing Gabbro

### Pieces 1A-3B (top), and 3D-5

**COLOR:** Gray. Greenish gray near veins.
**LAYERING:** Possible modal layering, local concentrations of olivine and plagioclase (troctolitic) at top of Piece 3A and middle of Piece 4C.
**DEFORMATION:** Weakly foliated near fractures.
Pieces 3A, 3B, 4A, and 4C: Local recrystallization and granulation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%, 70% in troctolitic zones.
Crystal size: 2-40 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 38%, 5% in troctolitic zones.
Crystal size: 4-22 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 2%, 25% in troctolitic zones.
Crystal size: 2-12 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-15%.
Texture: Not determined.
Percent vein material: 5%.
Vein material: Pieces 1B-3B and 4C: Green amphibole in veins, often associated with white mineral (granulated plagioclase?).
**COMMENTS:** Pieces 3 and 4D: Localized concentrations of ilmenite and sulfides.

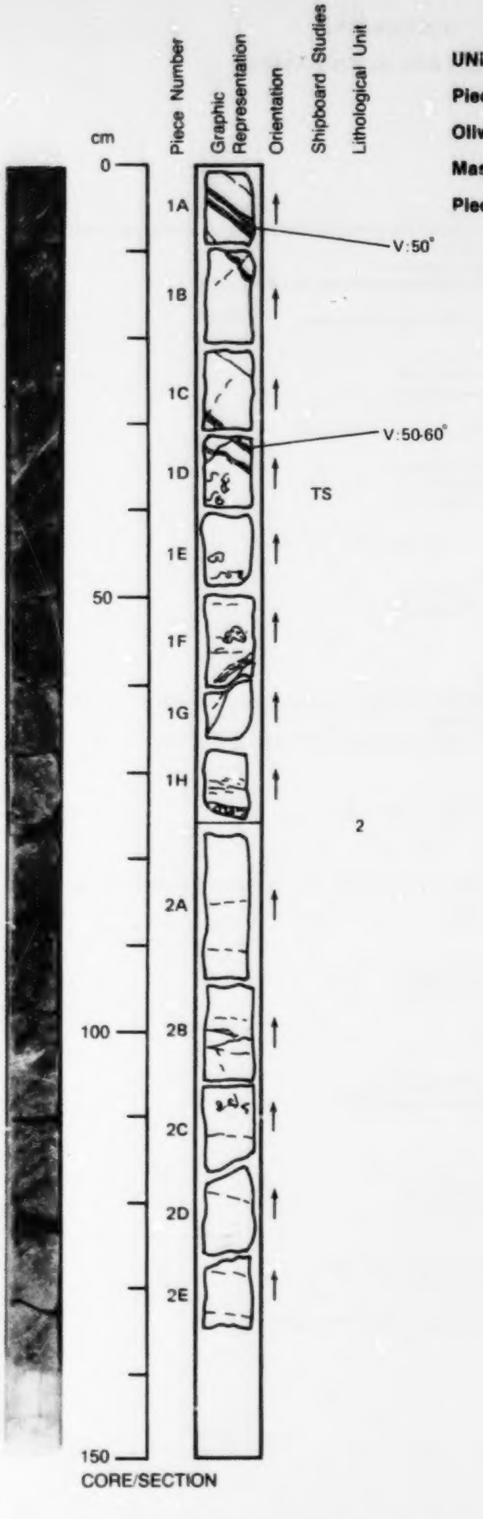
### Porphyroclastic Metagabbro

### Pieces 3B (bottom), 3C, and 4A (side)

**COLOR:** Greenish gray.
**LAYERING:** Massive.
**DEFORMATION:** Weakly foliated porphyroclasts of pyroxene, recrystallized pyroxene and plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-65%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.

Olivine—10%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Green amphibole replacing pyroxenes.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Localized concentrations of ilmenite and sulfides.



**118-735B-31R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-2E**

**Olivine Gabbro**

**Massive, Locally Foliated, Amphibolitized Gabbro**

**Pieces 1A-2E**

**COLOR:** Variations on gray, green near veins, white where veins contain sodic plagioclase (Pieces 1A, 1C, and 1D), speckled brown in Piece 1E (olivine pseudomorphs) and white in Piece 1F talc (?) after olivine.

**LAYERING:** Vague: goes from coarse to very coarse from Piece 1A to 1B, 2A to 2B, fine-grained from Piece 2D to 2E. Fine layering pyroxene/plagioclase in Piece 1D.

**DEFORMATION:** Small faults offsetting veins in Pieces 1A, 1C, and 1D. Inclined fractures in Pieces 1F and 1G; near horizontal fractures in Pieces 2A-2E. Some near horizontal foliation in Pieces 1H and 2D.

**PRIMARY MINERALOGY:**

Plagioclase—50-60%.
Crystal size: Not determined.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Some replacement by albite.

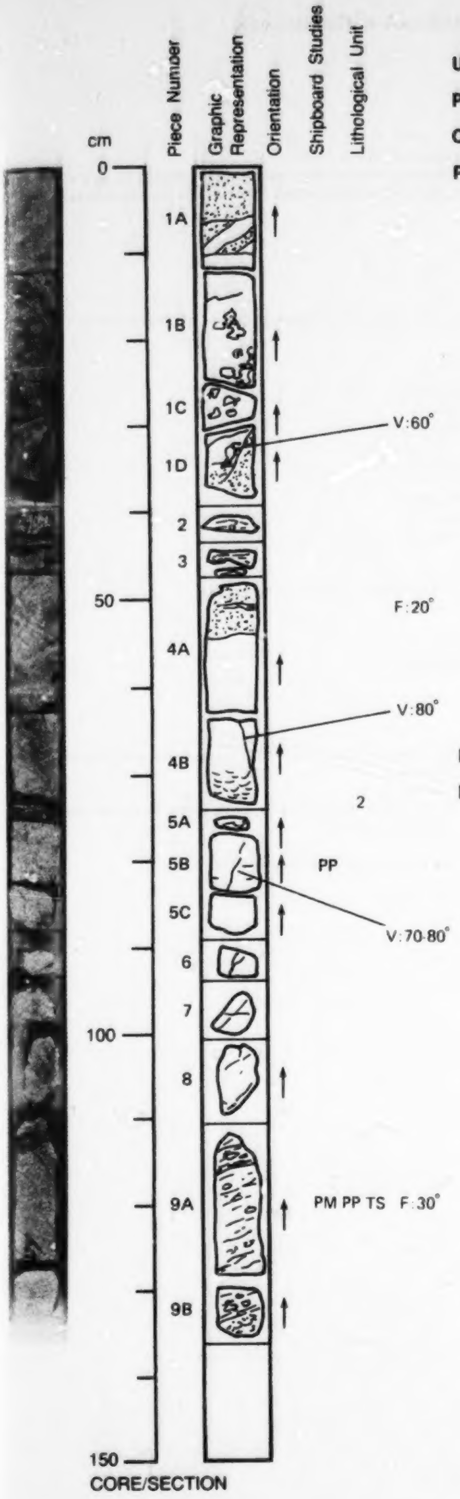
Clinopyroxene—Mode: Present, may also contain orthopyroxene.
Crystal size: Not determined.
Crystal shape: Subophitic, locally euhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Some replacement by amphibole.

Olivine—Mode: Not determined but present at base of upper coarsening sequence in Piece 1F.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Green amphibole in most pieces concentrated near veins. Albite in bleached looking pegmatitic material in Piece 2B. Talc on fracture surfaces near amphibole. Ilmenite/magnetite patches in most pieces forming 1%-2%. No sulfides.
Percent vein material: Not determined.
Vein material: Fracture surfaces lined with pale green talc and amphibole. The amphibole is well crystallized and is oriented along slip surfaces, slightly oblique from vertical in the plane of the fracture.

**COMMENTS:** Graphic representation is of the working half of core, not the archive half.



## 118-735B-31R-4

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-9B

### Olivine-Bearing Gabbro

### Pieces 1A-1D

**COLOR:** Gray or greenish gray.
**LAYERING:** Size and modal layering in Pieces 1A-1D, from the top: 6-cm-thick layer, fine-grained; clinopyroxene-rich layer; 1.5 cm thick, medium-grained, plagioclase-rich layer; 1.5 cm thick, fine-grained, clinopyroxene-rich layer; 20 cm thick, plagioclase-rich layer; and 5 cm thick, medium-grained, clinopyroxene/plagioclase (ratio 1:1) layer. Weakly foliated layers dip at 50°.
**DEFORMATION:** Weakly deformed, locally faulted (e.g., in Piece 1A) and sheared.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-70%.
Crystal size: 0.5-2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not clear.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-40%.
Crystal size: 0.5-2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not clear.
Percent replacement: 10% by amphibole.

Olivine—Mode: 1%-3%.
Crystal size: 0.3-10 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Not clear.
Percent replacement: <2% by tremolite and mica or talc.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Not determined.
Percent vein material: Not determined.
Vein material: Piece 1A: Amphibole vein with dip component present.

### Metamorphosed Olivine Gabbro

### Pieces 2-4A (top)

**COLOR:** Greenish gray.
**LAYERING:** None except for a thin plagioclase-rich band in Piece 4A. Piece 2 and the leucocratic part of Piece 4A contain clinopyroxene, a few millimeters across, as phenocrysts(?) or as porphyroclasts. Remainder of unit is homogeneously fine-grained (<0.5 mm).
**DEFORMATION:** Well-foliated.
**PRIMARY MINERALOGY:** Due to the small grain size, primary mineralogy was not determined.
**SECONDARY MINERALOGY:**
Total percent: >25%.
Texture: Amphibole replaces clinopyroxene.
Percent vein material: None.
Vein material: None.

**118-735B-31R-4 (continued)**

## Olivine-Bearing Metagabbro

### Pieces 4A (bottom)-8

**COLOR:** Gray or greenish gray.
**LAYERING:** No layering. Grain size ranges from 0.5 to 7 cm.
**DEFORMATION:** Pieces 4A-4B: Gray, relatively massive and weakly foliated. Pieces 5A-5C and 6-8: Greenish gray, foliated, deformed, and amphibolitized. These pieces are also pervasively veined by amphibole.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 0.5-2 cm.
Crystal shape: Euhedral.
Preferred orientation: Not clear.
Percent replacement: Replaced by sodium-rich plagioclase along amphibole veins.

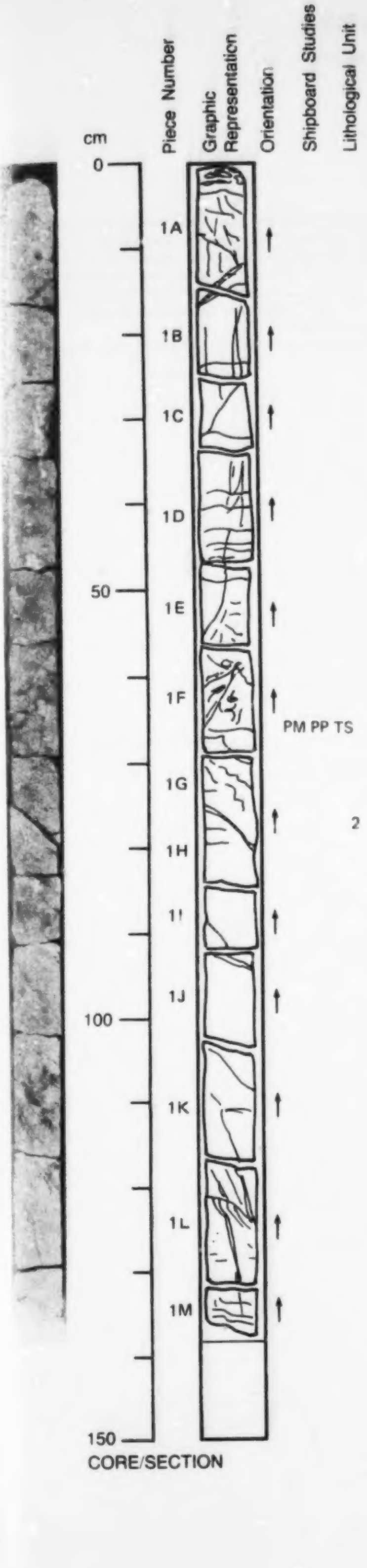
Clinopyroxene—Mode: 30%.
Crystal size: 0.5-1 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not clear.
Percent replacement: 30%-60% by amphibole.

Olivine—Mode: 3%.
Crystal size: 0.5-1 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Not clear.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 10%-30%.
Texture: Clinopyroxene replaced by various amounts of amphibole.
Percent vein material: Abundant.
Vein material: Amphibole.

## Well-Foliated Porphyroclastic Metagabbro

### Pieces 9A and 9B

**COLOR:** Greenish gray to gray.
**LAYERING:** Piece 9A: Melanocratic layer (opaque-rich, 2 cm thick) is present. Piece 9B (bottom) is leucocratic, suggesting modal layering.
**DEFORMATION:** Porphyroclastic-well foliated.
**PRIMARY MINERALOGY:** Similar to Pieces 4A-8, the olivine-bearing metagabbro described above, except for opaque-rich and leucocratic layers.
**SECONDARY MINERALOGY:**
Similar to Pieces 4A-8, the olivine-bearing metagabbro described above.



**118-735B-32R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1M**

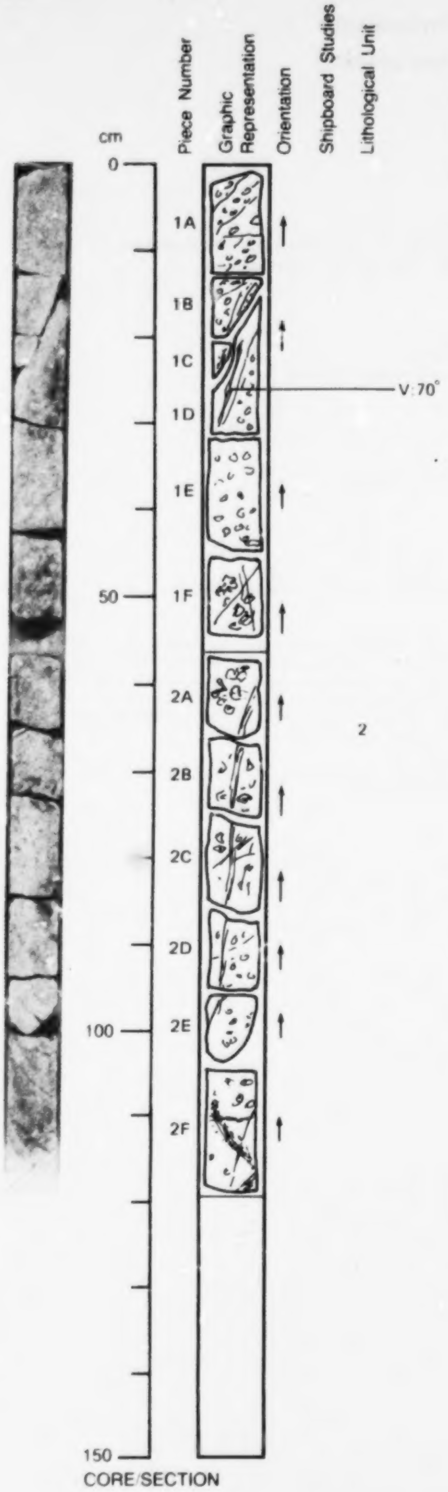
### Olivine-Bearing Gabbro

**Pieces 1A-1M**

**COLOR:** Medium gray to dark gray.
**LAYERING:** None—ilmenite concentrations at 62 cm.
**DEFORMATION:** Cataclastic textures in Pieces 1A, 1L, and 1M—granulated plagioclase and common amphibole veins in those pieces. Weak foliation in Piece 1M.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 0.5-50 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Occasionally replaced by albite.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 0.5-30 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.

Olivine—Mode: 0%-2%.
Crystal size: 0.3-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partially replaced by talc-tremolite-serpentine.
**SECONDARY MINERALOGY:**
Total percent: Up to 90% (?).
Texture: In deformed sections green amphibole partially replaces clinopyroxene (< 10%). Green amphibole and a white mineral (albite) + sulfides in veins and veinlets. Fine sulfides throughout. Plagioclase is sometimes replaced by albite. Olivine is partially replaced by talc-tremolite-serpentine. Iron-titanium oxides enriched in Piece 1F and at the bottom of Piece 1D, filling interstices and reaching 15%. Olivine is somewhat crushed in Piece 1B. In deformed zones, green amphibole replaces up to 90% of the rock.
Percent vein material: Not determined.
Vein material: Veins up to 1 cm across, consisting preferentially of green amphibole, albite, and sulfide. Disseminated sulfides common.



**118-735B-32R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-2F**

### Partly Amphibolitized Olivine-Bearing Gabbro

**Pieces 1A-2F**

**COLOR:** Gray to dark gray.

**LAYERING:** Size and modal layering—from the top to the bottom: 3 cm thick, clinopyroxene-rich layer, grainsize = 3 mm; 3 cm thick, clinopyroxene/plagioclase (ratio 1:1) layer 5-8 mm; Pieces 1B-2A gradually increases from 3 mm to >10-20 mm, clinopyroxene/plagioclase (ratio 1:1) nearly constant—Clinopyroxene is oikocrystic; Pieces 2A-2E, grain size decreases gradually from 10-20 mm to >5 mm, clinopyroxene/plagioclase ratio is constant; and Piece 2F, 3 mm sized clinopyroxene-rich layers, 4 cm thick, is sandwiched between 10-15 mm grain-sized, plagioclase-rich layer inclined at 40°. Weakly foliated.

**DEFORMATION:** Minor, localized: (1) weak deformation along amphibole + chlorite vein. (2) bottom of Piece 2F is sheared.

**PRIMARY MINERALOGY:**

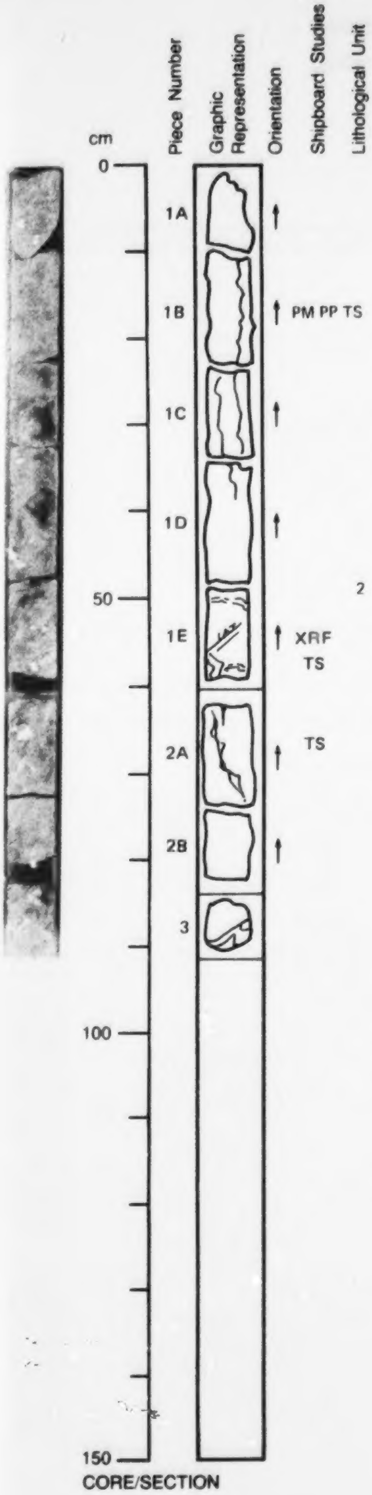
Plagioclase—Mode: 50%-65%.
Crystal size: Various, up to 25 mm.
Crystal shape: Euhedral-anhedral.
Preferred orientation: Weak.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%-30%.
Crystal size: Various, up to 20 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Weak.
Percent replacement: 5%-15% by amphibole.

Olivine—Mode: 2%-3%.
Crystal size: Various, up to 10 mm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Weak.
Percent replacement: Rimmed by tremolite + talc or mica aggregates.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Amphibole replacing clinopyroxene is intense near amphibole and chlorite veins.
Percent vein material: Abundant.
Vein material: Amphibole + chlorite, dipping at 70°-80° or 10°.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
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150
1A
1B
1C
1D
1E
2A
2B
3
PM PP TS
XRF
TS
TS
2
CORE/SECTION

**118-735B-32R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-3**

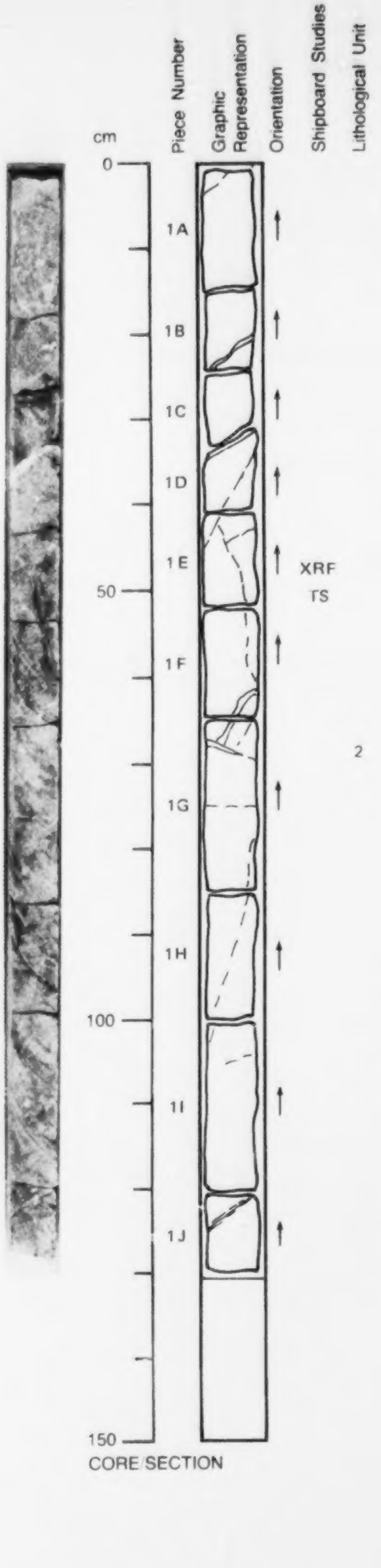
**Olivine-Bearing Gabbro**

**Pieces 1A-3**

**COLOR:** Dark gray, mottled.
**LAYERING:** None obvious. Increase in grain size toward bottom of section.
**DEFORMATION:** No foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: < 10% replacement by sodic plagioclase.

Clinopyroxene—Mode: 40%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: < 10% replacement by amphibole.

Olivine—Mode: 10%.
Crystal size: 1-4 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: 50% by talc + tremolite.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Not determined.
Percent vein material: 10%.
Vein material: Sheared sodic plagioclase + actinolite. Pieces 1B-1D: Vertical amphibole veins. Pieces 1E-3: Amphibole + sodic plagioclase veins containing euhedral hornblende crystals up to 5 cm long.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1J
XRF
TS
2
CORE SECTION

**118-735B-32R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1J**

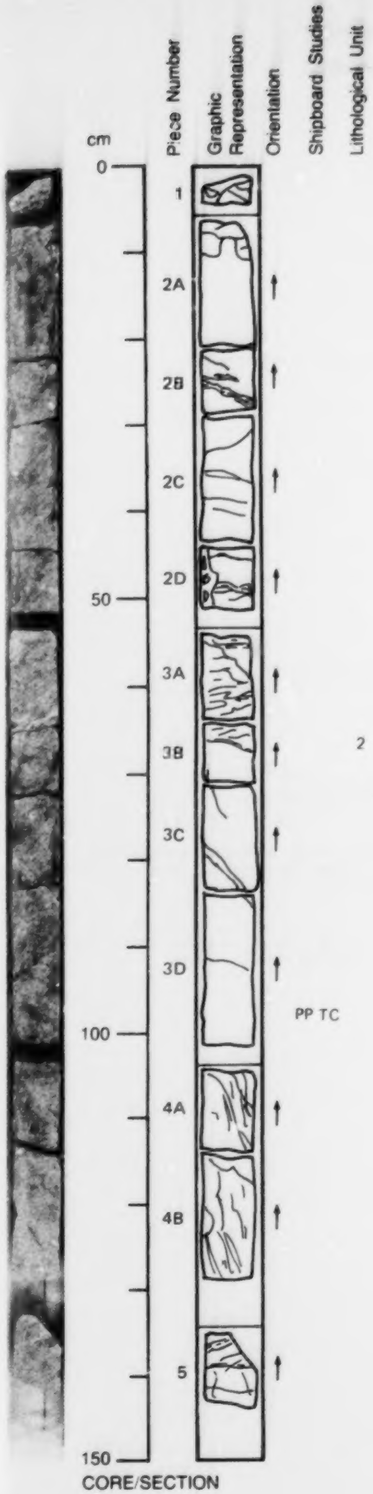
**Massive Gabbro**

**Pieces 1A-1J**

**COLOR:** Gray to greenish-gray.
**LAYERING:** Coarse-grained throughout, except for a medium-grained section in Piece 1A.
**DEFORMATION:** Fractures as indicated. Piece 1J: Some granulation/foliation next to fracture.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: Not determined.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Moderate.

Clinopyroxene—Mode: 40%-60%.
Crystal size: Very large in Pieces 1A, 1F, and 1G.
Crystal shape: Rarely encloses plagioclase subophitically.
Preferred orientation: None.
Percent replacement: Moderate alteration to amphibole.

Olivine—Mode: 5%-10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive—replacing mineral not determined.
**SECONDARY MINERALOGY:**
Total percent: Moderate.
Texture: Pervasive slight alteration of clinopyroxene to green amphibole. Scattered ilmenite throughout, but no more than 1%-2% of the rock.
Percent vein material: Not determined.
Vein material: Green amphibole and pale sodic plagioclase near some veins. Talc on other fracture surfaces.
**COMMENTS:** Both clinopyroxene and plagioclase are cumulus and intercumulus minerals.



## 118-735B-33R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-5

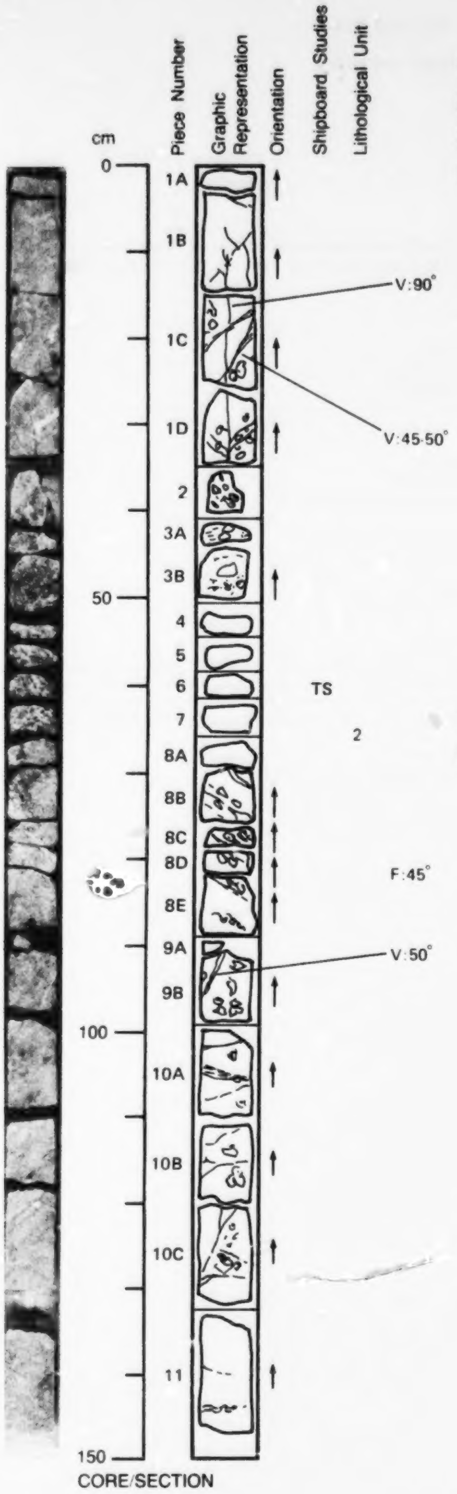
### Olivine-Bearing Gabbro

### Pieces 1-5

**COLOR:** Gray to greenish-gray.
**LAYERING:** None.
**DEFORMATION:** Shear zone in Pieces 2B-2C; some deformation in Piece 4B. Prominently foliated to porphyroclastic gabbro in Pieces 1, top of 2A, 2D, 3A, top of 3B, and 5. Left part of Piece 2D includes a near vertical shear zone.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly albitized.

Clinopyroxene—Mode: 45%.
Crystal size: Up to 2.5 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Variably altered to amphibole.

Olivine—Mode: 0%-5%.
Crystal size: <3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Talc-tremolite rims.
**SECONDARY MINERALOGY:**
Total percent: <20% to 40%.
Texture: Green amphibole replaces clinopyroxene. Amphibole, albitic plagioclase, and sulfides in veins and veinlets—sulfide disseminated throughout. Olivine with talc-tremolite rims. Deformed sections have more extensive amphibolitization. Plagioclase is also partly albitized. Undeformed sections contain similar veins and sulfides although veining may be more common.
Percent vein material: Not determined.
Vein material: Amphibole, albitic plagioclase and sulfides.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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50
100
150
1A
1B
1C
1D
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3A
3B
4
5
6
7
8A
8B
8C
8D
8E
9A
9B
10A
10B
10C
11
V:90°
V:45-50°
TS
2
F:45°
V:50°
CORE/SECTION

## 118-735B-33R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-11

### Olivine-Bearing Gabbro

### Pieces 1A-1D

**COLOR:** Gray with white bands.
**LAYERING:** No marked layering.
**DEFORMATION:** Weak, along veins slightly sheared.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 5-20 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Replaced by sodic plagioclase along veins.

Clinopyroxene—Mode: < 35%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral, oikocrystic.
Preferred orientation: None.
Percent replacement: 5%-10% by amphibole.

Olivine—Mode: Up to 5%, locally concentrated.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Moderately by tremolite + talc or mica.
**SECONDARY MINERALOGY:**
Total percent: 5%-15%.
Texture: Not determined.
Percent vein material: Not determined.
Vein material: Amphibole and albite veins (2-8 mm thick).
**COMMENTS:** Clinopyroxene is commonly oikocrysts including euhedral plagioclase.

### Extensively Amphibolitized Gabbro

### Pieces 2-8E (top)

**COLOR:** Greenish gray. Pieces 3C-8E are milky white with gray parts.
**LAYERING:** Weakly foliated, porphyritic appearence is magmatic in origin (?). Grain size variation is apparent, but irregular.
**DEFORMATION:** Pieces 2-3B: No marked deformation. Pieces 3C-8E (top): Porphyroclastic. Porpyroclasts are clinopyroxene and plagioclase. Foliation due to the deformation dips at 45°.
**PRIMARY MINERALOGY:** Not clear due to metamorphism.
**SECONDARY MINERALOGY:**
Total percent: >40%.
Texture: Clinopyroxene is replaced by amphibole; 30%-40% in Pieces 2-3B and 10%-15% in Pieces 3C-8E (top). Plagioclase is also altered into sodic plagioclase.
Percent vein material: Not determined.
Vein material: Not determined.

## 118-735B-33R-2 (continued)

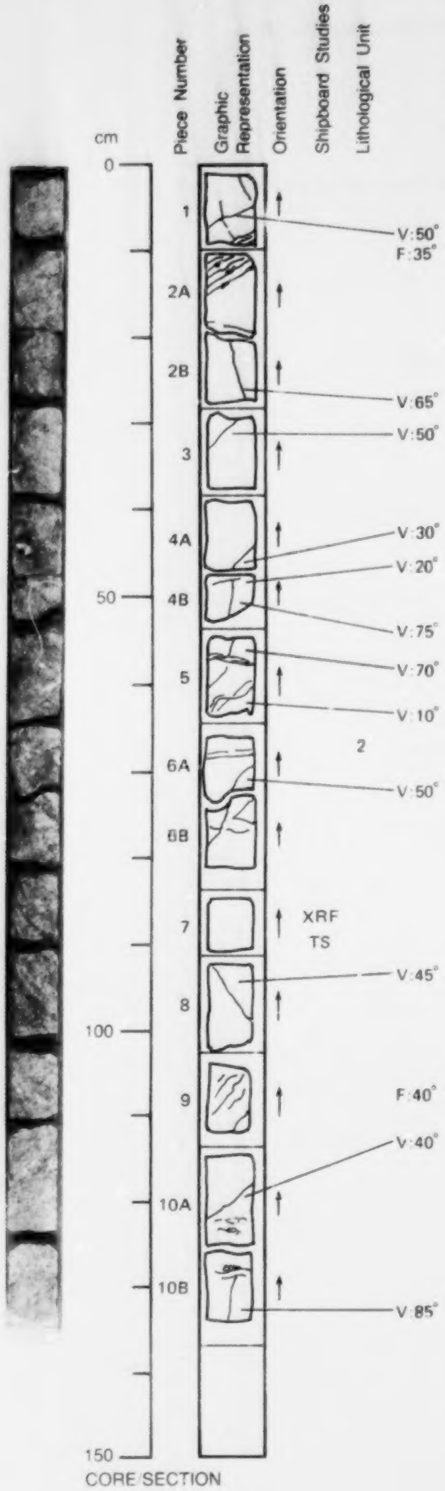
### Olivine-Bearing Gabbro

### Pieces 8E (bottom)-11

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Local. Piece 10A: 1 cm sheared zone inclined at 45°.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-2 cm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Fresh.

Clinopyroxene—Mode: 30%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral, oikocryst.
Preferred orientation: None.
Percent replacement: Trace, by amphibole.

Olivine—Mode: Up to 7%, locally concentrated in Pieces 8B and 8E.
Crystal size: Not determined.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 40%-60% by tremolite + talc or mica.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Not determined.
Percent vein material: Trace.
Vein material: Pieces 9B and 10A-10C: Milky albite veins are present, 2-3 mm thick.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1
2A
2B
3
4A
4B
5
6A
6B
7
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9
10A
10B
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V:65°
V:50°
V:30°
V:20°
V:75°
V:70°
V:10°
2
V:50°
XRF
TS
V:45°
F:40°
V:40°
V:85°
CORE/SECTION

**118-735B-33R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-10B**

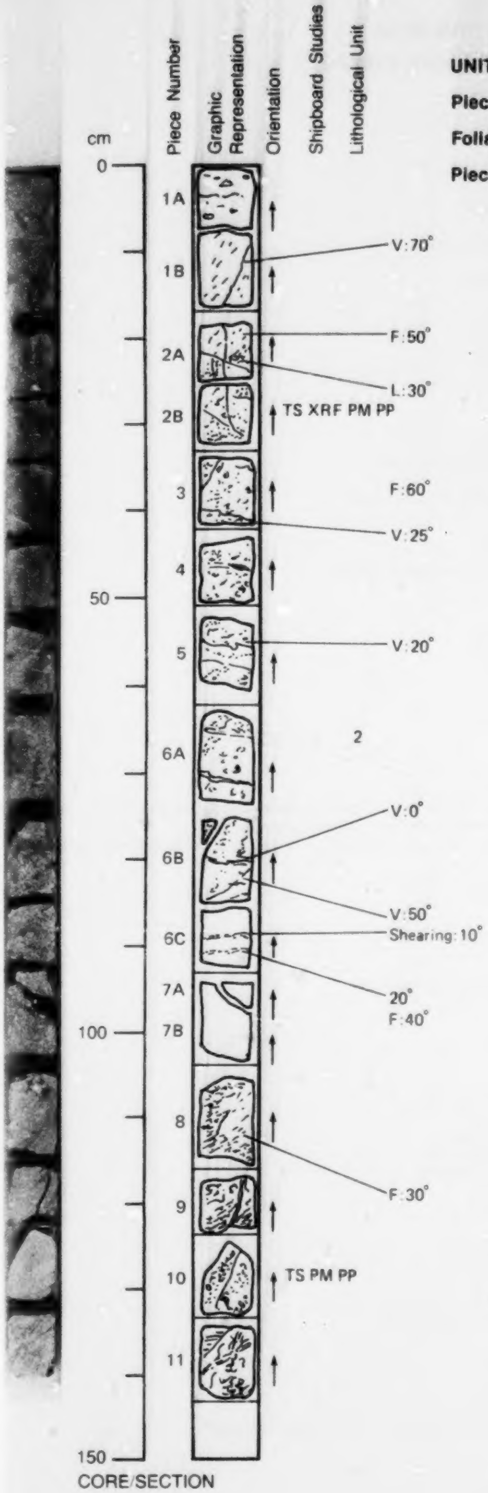
**Olivine Gabbro**

**Pieces 1-10B**

**COLOR:** Medium gray to greenish gray.
**LAYERING:** None.
**DEFORMATION:** Localized to discrete shear zones in Pieces 1, 2A, 10A, and 10B.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Medium to coarse.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Albitized between 116-132 cm.

Clinopyroxene—Mode: 40%.
Crystal size: Medium to coarse.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Partially replaced by amphibole.

Olivine—Mode: 5%.
Crystal size: Medium to coarse.
Crystal shape: Subhedral and anhedral.
Preferred orientation: Not determined.
Percent replacement: Rims of talc and tremolite.
**SECONDARY MINERALOGY:**
Total percent: < 10%.
Texture: Green amphibole partially replaced clinopyroxene. Plagioclase is albitized between 116-132 cm. Olivine has rims of talc and tremolite. Sulfide disseminated throughout.
Percent vein material: Variable.
Vein material: Green amphibole, + albite + sulfides.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
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1A
1B
2A
2B
3
4
5
6A
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6C
7A
7B
8
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11
V:70°
F:50°
L:30°
TS XRF PM PP
F:60°
V:25°
V:20°
2
V:0°
V:50°
Shearing: 10°
20°
F:40°
F:30°
TS PM PP
CORE/SECTION

**118-735B-33R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-11

### Foliated Olivine-Bearing Gabbro

### Pieces 1A-6B (top), 9, and 11

**COLOR:** Dark gray.

**LAYERING:** Size and modal layering as follows from top to bottom.

Pieces 1A-8A:
20 cm thick, 3-7 mm sized, olivine-poor, locally plagioclase-rich layer (Piece 2A, top);
5 cm thick, 0.5 mm sized (locally 2-1 mm), relatively olivine-rich layer;
9 cm thick, 0.7-2 mm sized, olivine-rich layer;
3 cm thick, 0.5-1 mm sized, olivine-poor, clinopyroxene-rich layer;
17 cm thick, 1-3 mm sized, locally plagioclase-rich, olivine-poor layer;
6 cm thick, 1 mm sized, clinopyroxene-rich layer.
8 cm thick, 10 mm sized, coarse-grained, and olivine-rich layer.
Clinopyroxene, plagioclase/olivine shows shape preferred orientation.
Foliation dips at 50° and layering dips at 30° are not parallel in Piece 2A, although they are parallel in Piece 3.

**DEFORMATION:** No marked deformation except for a few sheared zones, 1-4 mm thick, in Pieces 6A, 2A, and 11. The latter also shows porphyroclastic texture.

**PRIMARY MINERALOGY:**

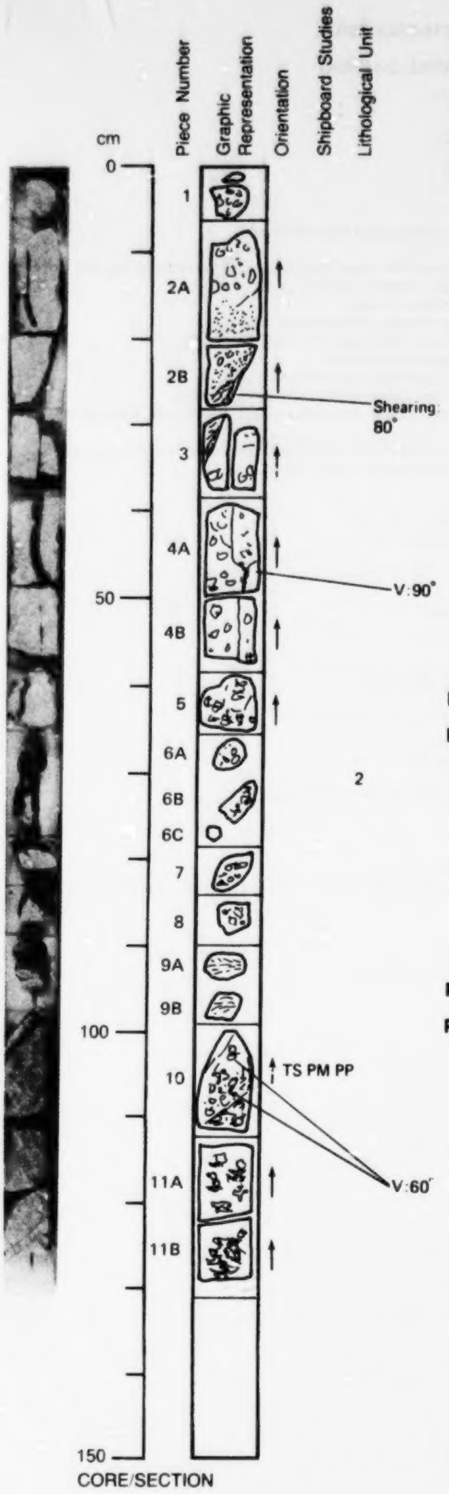
Plagioclase—Mode: 45%-65%.
Crystal size: Various, see above.
Crystal shape: Euhedral-anhedral.
Preferred orientation: Marked.
Percent replacement: None.

Clinopyroxene—Mode: 35%-20%.
Crystal size: Various, see above.
Crystal shape: Subhedral.
Preferred orientation: Marked.
Percent replacement: <5% by amphibole.

Olivine—Mode: 2%-10%.
Crystal size: Various, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Marked.
Percent replacement: Trace by tremolite + talc or mica.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Not determined.
Percent vein material: Abundant.
Vein material: Amphibole and albite, 1-3 mm thick, inclined at various angles.



## 118-735B-34R-1

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-11B**

### Olivine-Bearing Gabbro

**Pieces 1, 2A (top), 3, and 4**

**COLOR:** Gray.
**LAYERING:** No layering.
**DEFORMATION:** No substantial deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-65%.
Crystal size: 10-20 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 25%-30%.
Crystal size: 10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10% by amphibole.

Olivine—Mode: 4%-7%, locally concentrated.
Crystal size: 3-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 50% by tremolite and talc.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Not determined.
Percent vein material: Minor.
Vein material: Amphibole.

### Microgabbro with Sheared Part

**Pieces 2A (bottom) and 2B**

**COLOR:** Greenish gray.
**LAYERING:** No layering.
**DEFORMATION:** Strongly foliated near the sheared zone; no other deformation, gradational contact with the upper coarse gabbro. 3 mm clinopyroxene grains present.
**PRIMARY MINERALOGY:** Because of its small grainsize, the modal ratio, shape, and often texture, cannot be determined.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Amphibolitized.
Percent vein material: None.
Vein material: None.

### Fine-Grained Clinopyroxene Oikocrystic Gabbro

**Pieces 5-7**

**COLOR:** Grayish green.
**LAYERING:** No layering.
**DEFORMATION:** Partly veined and sheared.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-60%.
Crystal size: <1 mm (chadacryst).
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 15%-35%.
Crystal size: 10 mm (oikocryst).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5% by amphibole.

Olivine—Mode: 4%.
Crystal size: 0.5-1 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 50% by tremolite + talc or mica + opaques.

## 118-735B-34R-1 (continued)

**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Not determined.
Percent vein material: Trace.
Vein material: Amphibole.

### Amphibolitized Medium-Grained Gabbro

### Piece 8

No description

### Foliated and Amphibolitized Metagabbro

### Piece 9

**COLOR:** Greenish gray.
**LAYERING:** Not determined.
**DEFORMATION:** Strong foliation. Clinopyroxene (olivine) is completely replaced by amphibole.
**PRIMARY MINERALOGY:** Similar to microgabbro described above.
**SECONDARY MINERALOGY:** Similar to microgabbro described above

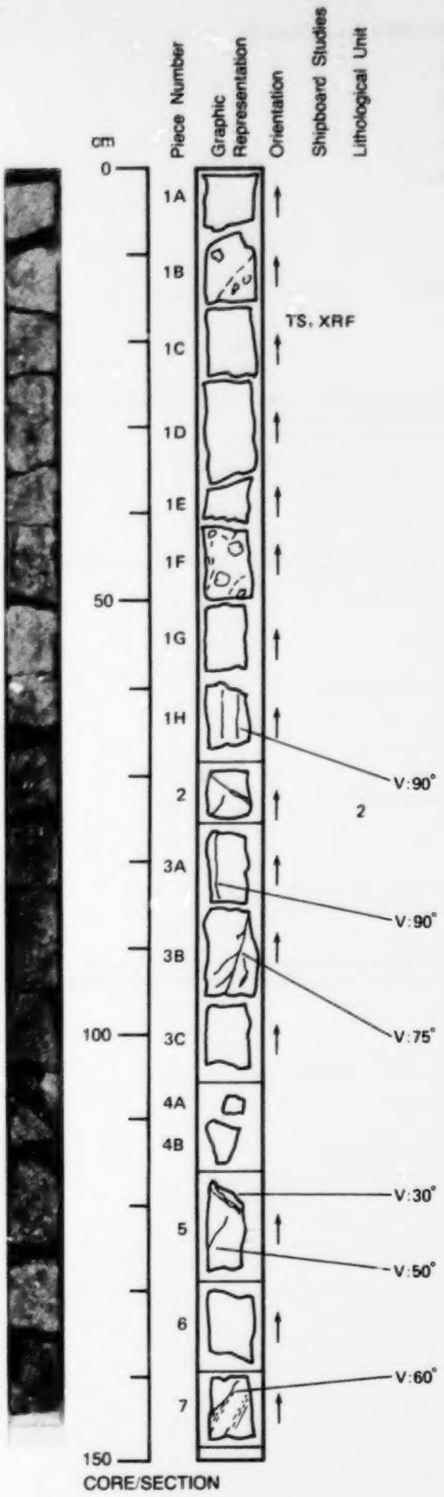
### Medium-Grained Clinopyroxene Oikocrystic Gabbro

### Pieces 10 and 11

**COLOR:** Gray.
**LAYERING:** No layering; clinopyroxene modal abundance increases from Pieces 11B to 11A to 10.
**DEFORMATION:** No deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-60%.
Crystal size: 2-10 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Trace by sodic plagioclase.

Clinopyroxene—Mode: 15%-35%.
Crystal size: 20-30 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Olivine—Mode: 10%-20%.
Crystal size: 3 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <10% by tremolite + talc or mica.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Slight replacement (clinopyroxene by amphibole <5%; olivine by tremolite + talc <10%). Piece 10: Along amphibole veins, plagioclase is albitized, and clinopyroxene is strongly replaced by amphibole.
Percent vein material: Trace.
Vein material: Amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
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1G
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3C
4A
4B
5
6
7
TS, XRF
2
V:90°
V:90°
V:75°
V:30°
V:50°
V:60°
CORE/SECTION

**118-735B-34R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-7

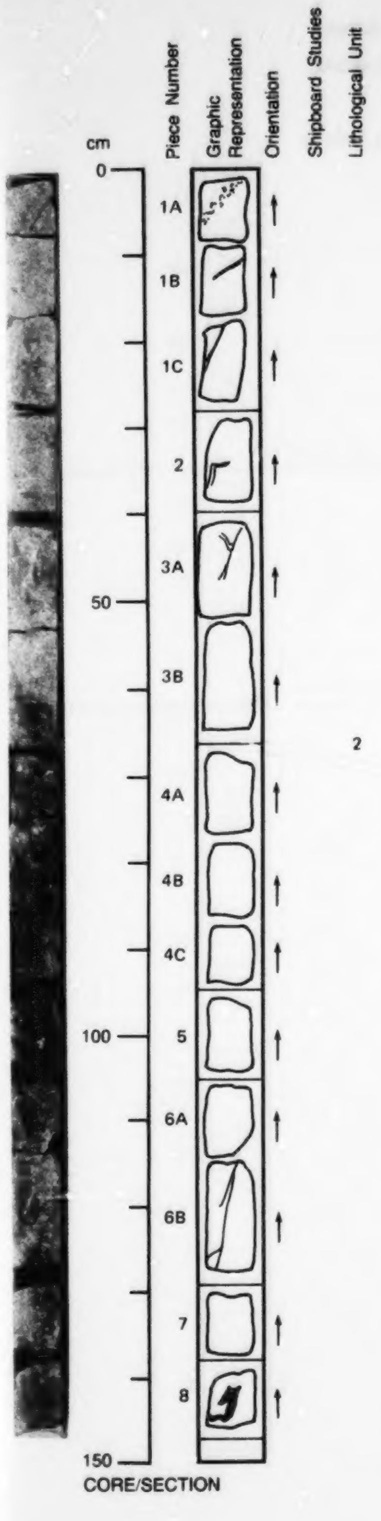
### Olivine-Bearing and Olivine Gabbro

### Pieces 1A-7

**COLOR:** Mottled greenish gray.
**LAYERING:** Grain-size variations: Pieces 1B and 1F: Grain size varies from 1 to 0.4 cm. Piece 7: Grain size varies from 0.7 to 0.2 cm.
**DEFORMATION:** No deformation except for sheared amphibole vein in Piece 5.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 70%.
Crystal size: 10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%-10% by albite, especially near the amphibole veins.

Clinopyroxene—Mode: 29%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral and oikocrystic.
Preferred orientation: None.
Percent replacement: 25% by green amphibole.

Olivine—Mode: 1%-27%.
Crystal size: <10 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Pseudomorphic.
Percent vein material: <2%.
Vein material: Amphibole and soft white mineral. Pieces 1H and 3A: Amphibole veins dipping at 90°. Piece 2: Green and white veins (amphibole) dipping at 30° and 50°. Piece 3B: Amphibole vein dips at 75° with albitized plagioclase around. Piece 4: Amphibole vein and albitization of plagioclase. Piece 5: Microshear zone with dark amphibole dipping at 30°; amphibole vein dips at 50°. Piece 7: Amphibole vein dipping at 60°.



### 118-735B-34R-3

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-8

### Olivine-Bearing Gabbro

### Pieces 1A-8

**COLOR:** Gray.

**LAYERING:** Possible modal layering with irregular concentrations of olivine (up to 10%) present in Pieces 4A, 4B, and 6B.
Grain size variations: Piece 1C is pegmatoidal with clinopyroxene up to 30 mm and plagioclase up to 50 mm. Fine-grained band across Piece 1A appears primary.

**DEFORMATION:** Minor. Granulation of plagioclase near fractures. Recrystallization of plagioclase around fracture at top of Piece 1B.

**PRIMARY MINERALOGY:**

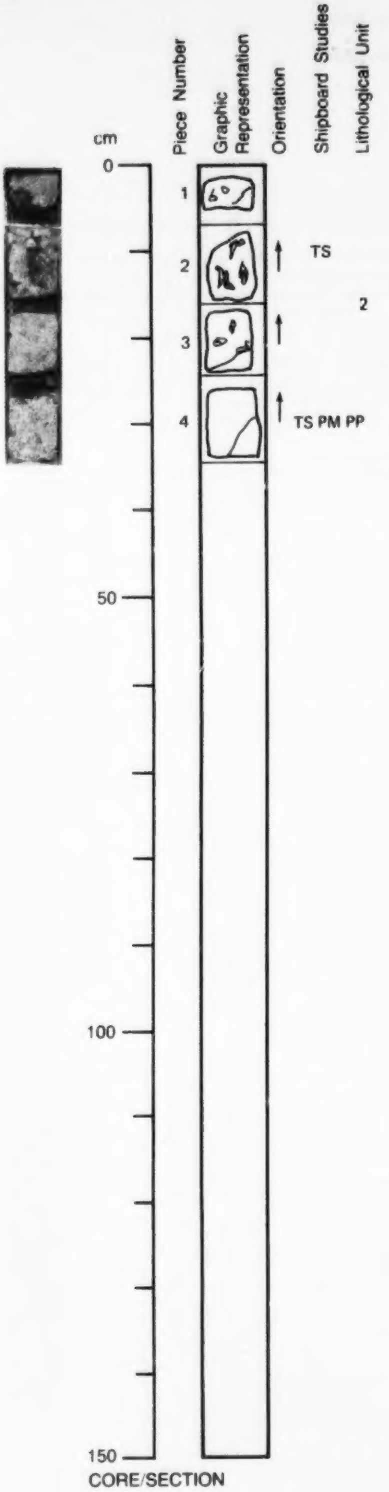
Plagioclase—Mode: 50%-70% (average 63%).
Crystal size: Norm 10-15 mm; range 1-50 mm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Altered to sodic plagioclase near fractures.

Clinopyroxene—Mode: 25%-45% (average 35%).
Crystal size: Norm 8-15 mm; range 1-30 mm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 2%-10%.
Crystal size: Norm 3-7 mm; range 1-12 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Alteration coronas of tremolite + talc + chlorite.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Plagioclase may be altered to sodic plagioclase, and may be granulated along fractures. Amphibole fills some fractures. Olivine exhibits alteration coronas, probably tremolite + talc + chlorite. Iron-titanium oxides concentrated in Piece 8 where it has the morphology of a clinopyroxene.
Percent vein material: Not determined.
Vein material: Pieces 1B, 3A, and 6B: Veins of sodic plagioclase and amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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50
100
150
1
2
3
4
TS
TS PM PP
2
CORE/SECTION

**118-735B-34R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-4**

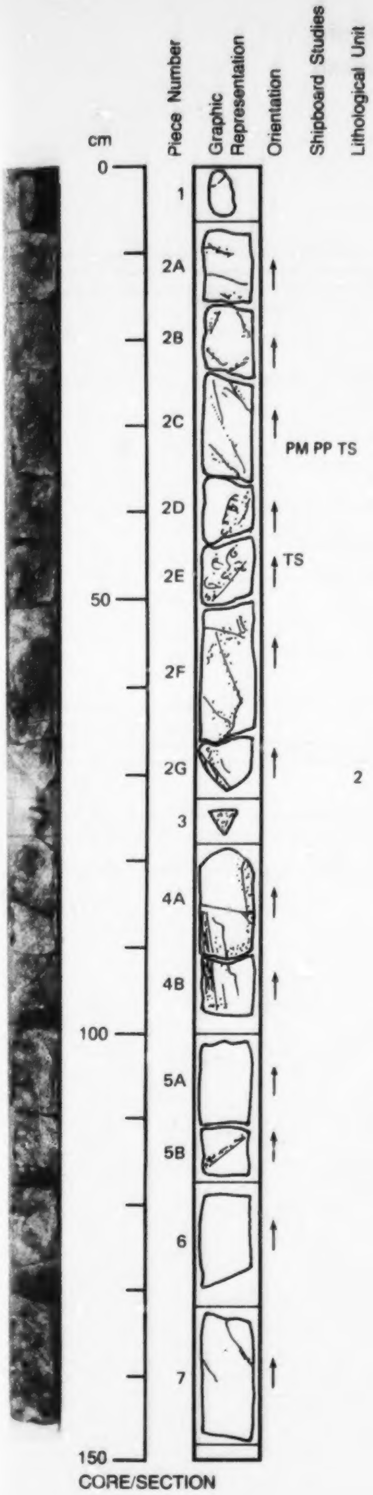
### Coarse-Grained Iron-Titanium Oxide-Bearing Gabbro

**Pieces 1-4**

**COLOR:** Dark gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-55%.
Crystal size: 10-30 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-35%.
Crystal size: 10-30 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: 30% by black amphibole in Pieces 1 and 2 and >70% by green amphibole in Pieces 3 and 4.

Olivine—Mode: <5%.
Crystal size: 10-30 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: >30%.
Texture: Pseudomorphic.
Percent vein material: <1%.
Vein material: One green amphibole vein in Piece 3.
**COMMENTS:** Primary or secondary(?) iron-titanium oxide: up to 15%-20%. Euhedral to anhedral in Piece 2.



**118-735B-35R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-7**

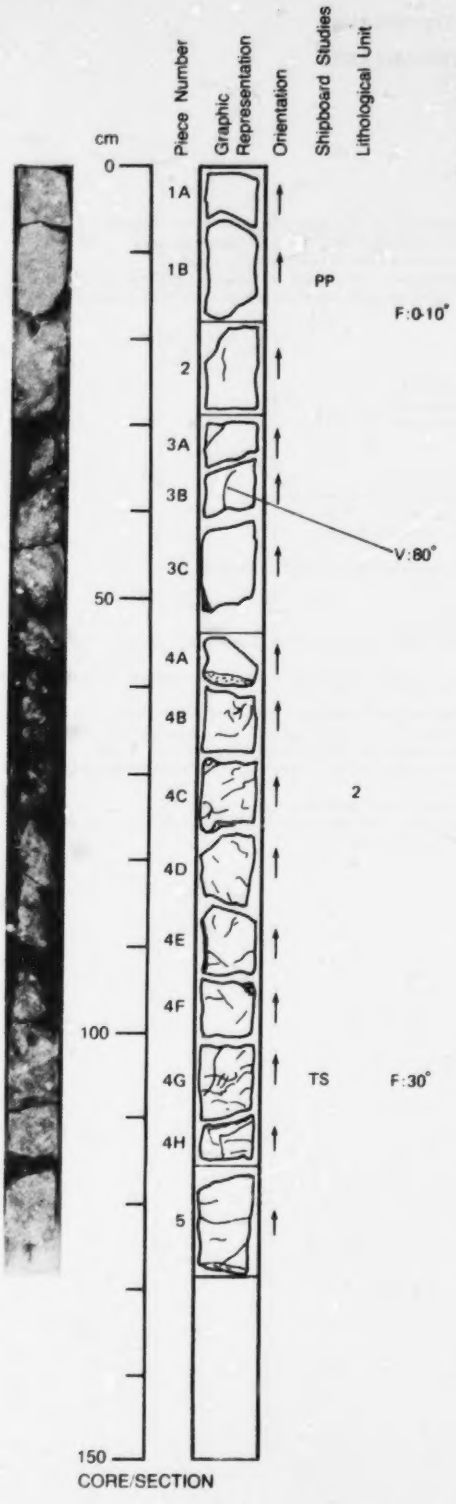
**Olivine Gabbro**

**Pieces 1-7**

**COLOR:** Gray.
**LAYERING:** Piece 7: Possible primary layering, i.e., thin layer, or concentration, of olivine.
Piece 2E: Fracture (back surface of archive half) filled with fibrous mineral.
Pieces 4A and 4B: Large vein (1-3 mm) filled with amphibole.
**DEFORMATION:** No foliation. Very coarse-grained on average, but variable. Extremely coarse-grained (2-4 cm grains) at 37-47 cm. Otherwise, grain size slightly finer at top than at bottom (below 50 cm).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%.
Crystal size: 5-40 mm (average 10 mm).
Crystal shape: Anhedral, some oikocrysts up to 40 mm.
Preferred orientation: Not determined.
Percent replacement: Variable, actinolite at rims.

Olivine—Mode: 5%-10%; somewhat greater in bottom of Piece 2.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Relatively fresh; some have halos of actinolite.
**SECONDARY MINERALOGY:**
Total percent: Moderate alteration. Total percentage of alteration at top 30%; decreases to less than 5%-10% at bottom.
Texture: Clinopyroxene replaced by green actinolite at rims. Plagioclase crosscut by thin actinolite filled fractures and veins. Olivine relatively fresh, but surrounded by halos of actinolite. Degree of alteration determined by abundance and proximity of veins.
Concentration of ilmenite and traces of sulfides in Piece 2E. Olivine has a yellowish alteration coating in Pieces 2D, 2E, and 6.
Percent vein material: Proportion of veins greatest at top of section.
Vein material: Actinolite or actinolite + albite. Pieces 4A and 4B: Green amphibole veins.
Piece 5B: Large (1-2 mm) vein, mainly albite.



118-735B-35R-2

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-5**

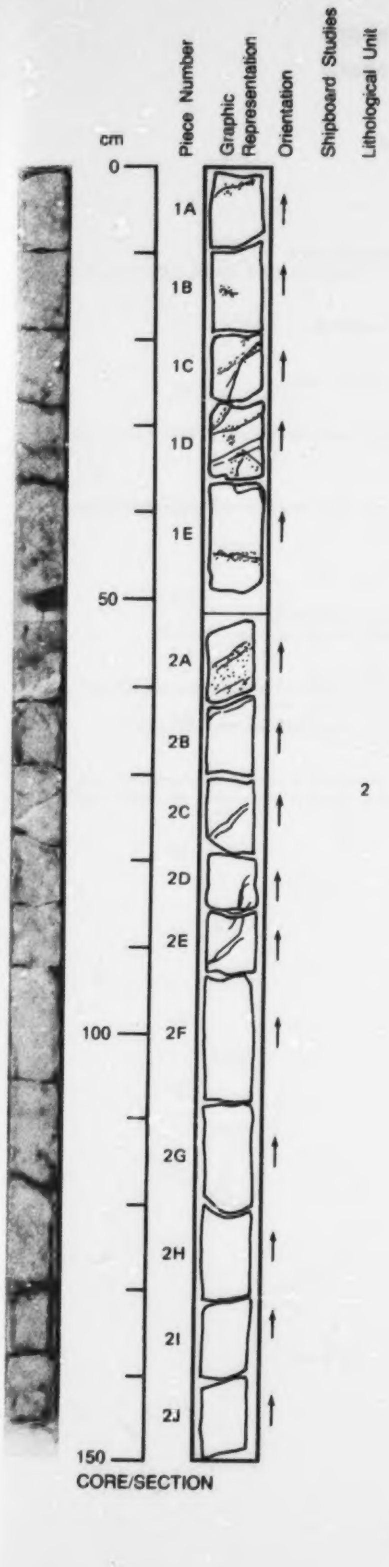
**Olivine Gabbro**

**Pieces 1A-5**

**COLOR:** Dark gray.
**LAYERING:** None apparent.
**DEFORMATION:** Foliation (well defined in Piece 1B) seen from flattened plagioclase and pyroxene. Piece 2B: Same minerals are stretched and elongated into the plane of foliation. Piece 4G: Brecciated-sheared zone, 8 mm thick, filled with plagioclase and little amphibole. Piece 1B: Grain size is reduced from centimeter to few millimeters.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-8 mm.
Crystal shape: Prismatic to lath-shaped, almost included in clinopyroxene or in the groundmass.
Preferred orientation: Not apparent.
Percent replacement: Slightly altered.

Clinopyroxene—Mode: 32%-48%.
Crystal size: Up to 40 mm.
Crystal shape: Mostly oikocrysts with irregular outlines.
Preferred orientation: Not apparent.
Percent replacement: Slightly altered to amphibole.

Olivine—Mode: 2%-8% (enriched zones in Pieces 4F and 4G).
Crystal size: 2-7 mm.
Crystal shape: Rounded to irregularly shaped.
Preferred orientation: Not apparent.
Percent replacement: 100% by serpentine + magnetite.
**SECONDARY MINERALOGY:**
Total percent: 35%.
Texture: Clinopyroxene is partly replaced by amphibole. Olivine is replaced by serpentine + magnetite and rimmed by talc (net texture). Probably amphibole (cummingtonite) is present in the coronitic arrangement. Olivine can also be altered into iron hydroxides and rusty brown clays. Plagioclase is recrystallized into smaller plagioclase grains and cut by green amphibole veins.
Percent vein material: Not determined.
Vein material: Veins are filled by amphibole or plagioclase or both (3-4 mm). Fractures are <1 mm thick and are responsible for some displacement in the rock. Piece 4G: Shears are filled with plagioclase (80%) and amphibole 20%.
**COMMENTS:** All pieces are olivine gabbro except for Piece 1B, which is a foliated olivine gabbro, and Piece 2B, which is a porphyroclastic gabbro.



**118-735B-35R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-2J**

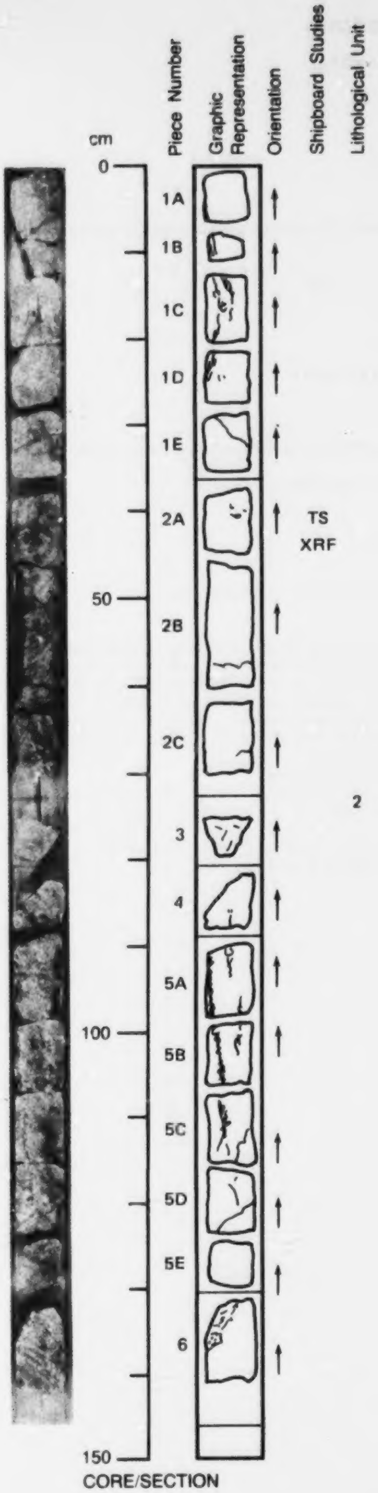
**Massive Olivine Gabbro**

**Pieces 1A-2J**

**COLOR:** Gray.
**LAYERING:** Possible primary layering. Pieces 1E and 1F: Concentrations of olivine in layers between clinopyroxene oikocrysts.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-50%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: None.
Percent replacement: Slight to moderate albitization.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 5-40 mm.
Crystal shape: Anhedral to subhedral, subophitic. Large oikocrysts in Pieces 1D and 1E.
Preferred orientation: None.
Percent replacement: Slight to moderate replacement by actinolite.

Olivine—Mode: 5%-15%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive to complete replacement by actinolite + talc.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Pieces 1A-1D: Alteration due to numerous thin, anastomosing, actinolite-filled fractures. Olivine with actinolite halos and crosscut by meshlike, dark alteration mineral. Some infilling of mesh by talc. Piece 2A: Intense albitization, approximately 1 cm wide at 60 62 cm. Concentration of ilmenite in a layer approximately 5 mm thick at 52-29 cm. Traces of sulfides throughout. Oxidation is associated with the sulfides producing an orange staining
Below 70 cm: Total alteration much higher and more pervasive, associated with albite + actinolite + epidote(?) veins (50%-60% alteration).
Pieces 2E and 2G: Contains reddish-stained plagioclase.
Below 110 cm: Amount of actinolite less (i.e., clinopyroxene altered only around rims) but plagioclase still has a milky white appearance.
Percent vein material: 5%-15%.
Vein material: Sodium plagioclase + actinolite + epidote (?). Piece 2A: Large vein. Albitic center with ilmenite-rich zone at upper border and oxide staining.
**COMMENTS:** Coarse-grained primary texture.



**118-735B-35R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-6**

### Variously Amphibolitized Olivine Gabbro and Olivine-Bearing Gabbro

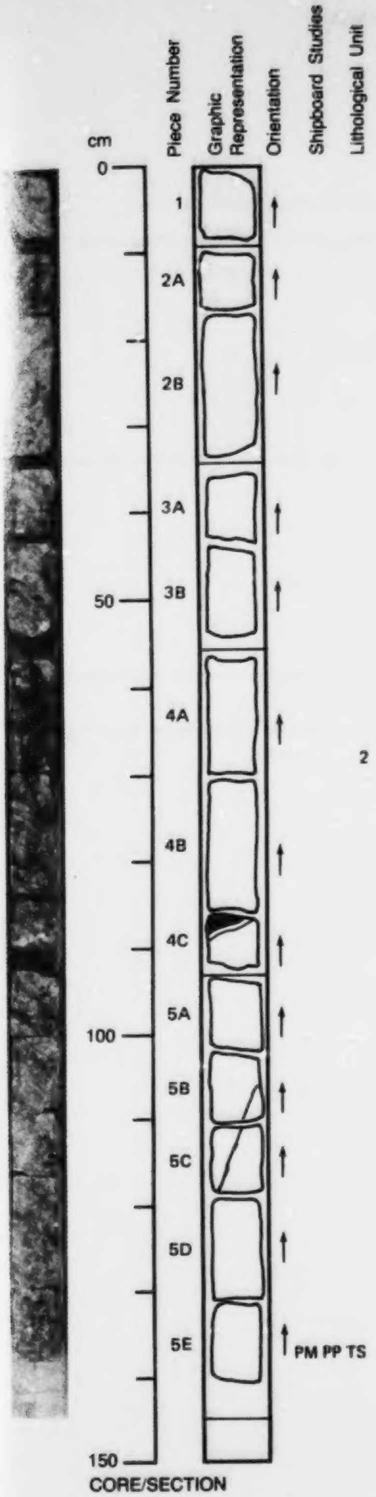
**Pieces 1A-6**

**COLOR:** Gray to green white.
**LAYERING:** No layering; however, spotty distribution of olivine.
**DEFORMATION:** Pieces 1, 5, and 6: granulation of plagioclase along near-vertical amphibole veins.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 2 mm (euhedral) to 20 mm (anhedral).
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Some albitization (?) near veins

Clinopyroxene—Mode: 40%.
Crystal size: Poikilitic to interstitial (5 mm); oikocrysts as large as 30 mm; 3 mm near euhedral clinopyroxene in Piece 3.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% to 50% by dark-green amphibole with granulation of plagioclase.

Olivine—Mode: 0%-8%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Up to 50% by talc and amphibole.
Distributed irregularly in core; particularly abundant in Pieces 5A and 5C.
**SECONDARY MINERALOGY:**
Total percent: Up to 50% replacement along veins.
Texture: Dark-green amphibole after clinopyroxene with granulation of plagioclase.
Percent vein material: Veins and altered zones form 5% of section.
Vein material: Veins are vertical, often with vuggy, incompletely filled spaces.
Pieces 1, 5, and 6: Amphibole.

**COMMENTS:** There are grain size variations in this section. A coarse-grained piece occurs at 75-80 cm, and there seems to be an indistinct fining upward to 40 cm, where the section again coarsens. The change is rather subtle.



**118-735B-35R-5**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-5E**

**Olivine-Bearing Gabbro**

**Pieces 1-5E**

**COLOR:** Gray.

**LAYERING:** Possible igneous layering indicated by gradations in grain size and texture along section (very coarse-grained to microgabbro).

**DEFORMATION:** Not determined.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-65%.
Crystal size: Variable, typically 0.5-4 mm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

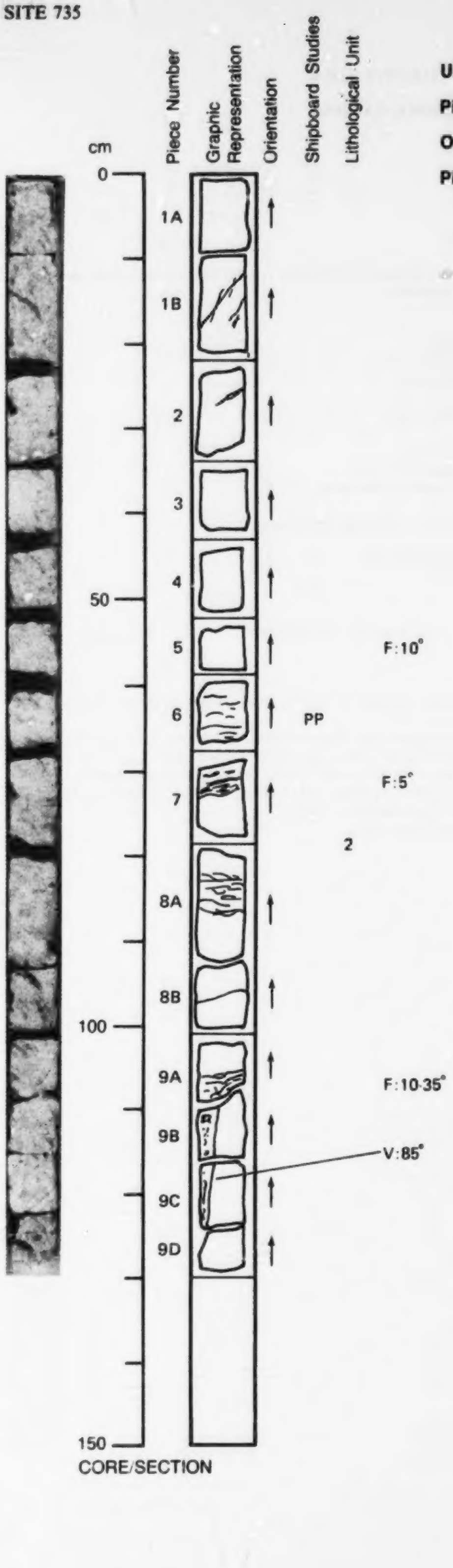
Clinopyroxene—Mode: 30%-40%.
Crystal size: Variable, but typically 1-4 mm.
Crystal shape: Anhedral, granular to subophitic.
Preferred orientation: None.
Percent replacement: 20% by talc, tremolite, and opaques.

Olivine—Mode: 1%-3% (pseudomorphs).
Crystal size: 0.5-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20% to talc, tremolite, and opaques.

**SECONDARY MINERALOGY:**

Total percent: 10%
Texture: Some local replacement of pyroxene by amphibole present. Olivine altered to talc, tremolite, and opaques.
Vein material: Amphibole and plagioclase. Green amphibole located in crosscutting veins along with feldspar. At least two generations: one amphibole vein, and a second of mixed plagioclase + amphibole veins (Pieces 5B and 5C) with darker colored amphibole.

**COMMENTS:** Anhedral granular to subophitic with pyroxene partially enclosing plagioclase laths.
Piece 4B: Apparent size and modal layering visible.
Piece 3C: Pyroxene-rich layer 15 mm thick.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
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1A
1B
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3
4
5
6
7
8A
8B
9A
9B
9C
9D
F:10°
PP
F:5°
2
F:10-35°
V:85°
CORE/SECTION

**118-735B-35R-6**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-9D**

**Olivine Gabbro**

**Pieces 1A-9D**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak foliation in Pieces 2, 3, 7, and 8, grading into deformed zones.
**PRIMARY MINERALOGY:**

As in Sections 118-735B-35R-4 and -5. A very coarse-grained (1-2 mm grains) interval in Pieces 9B-9D.

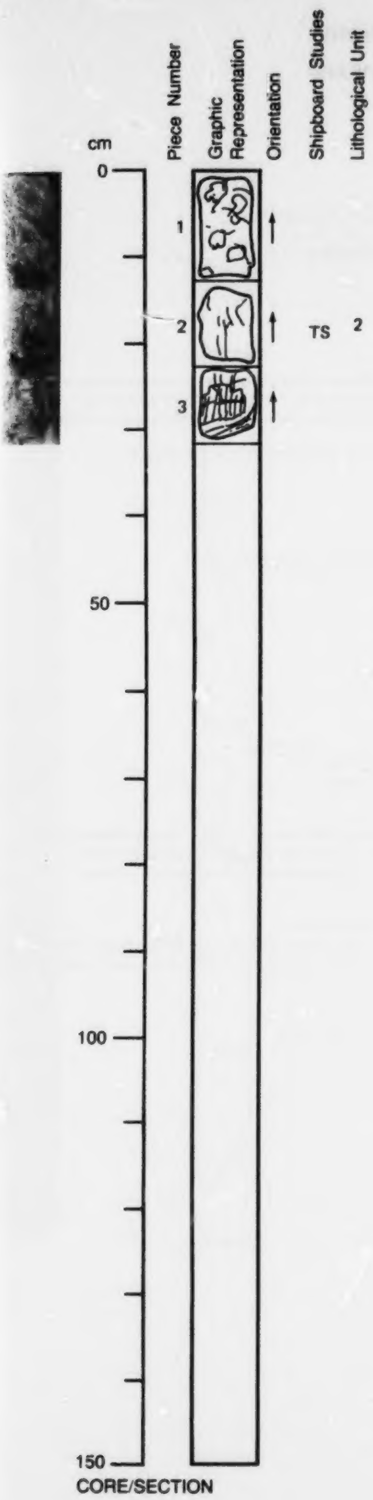
Plagioclase—Mode: 50%-60%.
Crystal size: 2-20.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Slight, near deformed zones.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-30 mm.
Crystal shape: Anhedral, poikilitic.
Preferred orientation: Slight near deformed zones Percent replacement: Variously replaced by green amphibole.

Olivine—Mode: 0%-10%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Variously replaced by talc/tremolite.

**SECONDARY MINERALOGY:**

Total percent: 10% (?) Percent vein material: <5%.
Vein material: Amphibole and feldspar.
Texture: Minor amphibole, feldspar vein fill.
Pieces 4-7 (top) and top of Piece 9: Slightly porphyroclastic to mylonitic olivine-bearing gabbro.
Pieces 7 and 9A: Mylonitic.
Pieces 9B and 9C: Vertical fracture with some plagioclase granulation and amphibole. Looks as if the fracture cuts the foliation.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1
2
TS
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3
50
100
150
CORE/SECTION

**118-735B-35R-7**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-3**

**Olivine Gabbro**

**Pieces 1-3**

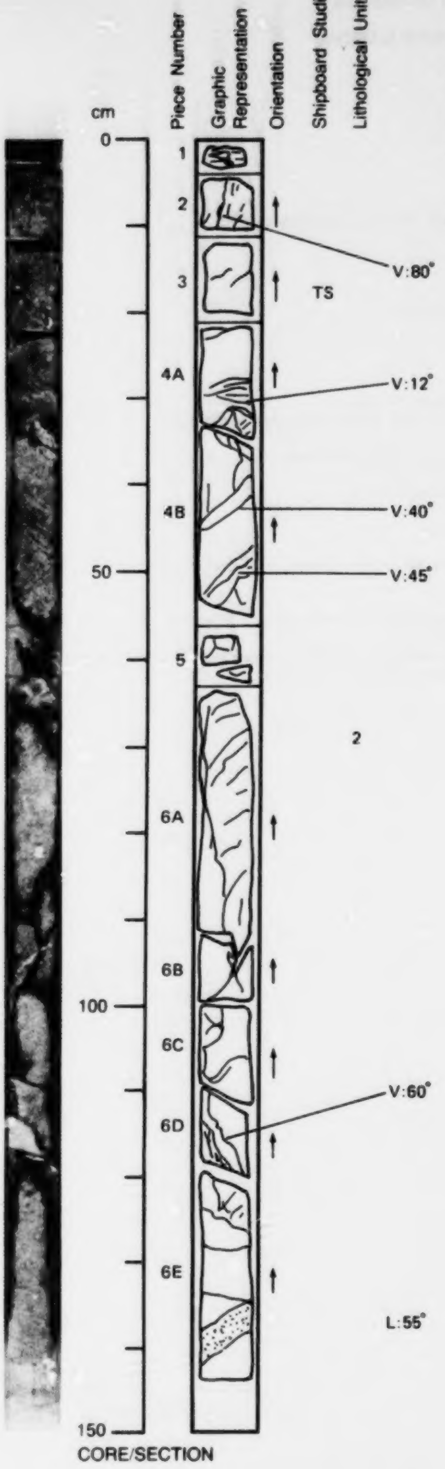
**COLOR:** Brownish gray.
**LAYERING:** None apparent.
**DEFORMATION:** None apparent, but base of Piece 3 is slightly sheared.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 65%.
Crystal size: 1-7 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 30%.
Crystal size: 3-20 mm (wide), 10-50 mm long.
Crystal shape: Irregular oikocryst (can contain plagioclase inclusions).
Preferred orientation: None.
Percent replacement: Slight by dark green amphibole.

Olivine—Mode: 5% (10% in Pieces 2 and 3).
Crystal size: 3-11 mm (Up to 20 mm in Pieces 2 and 3).
Crystal shape: Rounded, irregular.
Preferred orientation: None.
Percent replacement: Slight by clays, iron hydroxides, magnetite, and talc.

**SECONDARY MINERALOGY:**
Total percent: <25%.
Texture: Plagioclase is strained and partly transformed to granoblasts.
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole. Fractures cut all pieces and show preferential alteration near the walls. Fractures are up to 1 mm thick.



**118-735B-36R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1-6E

### Strongly Foliated Mylonitized Metagabbro

### Piece 1

No description—may have come from higher level in the hole.

### Medium- to Coarse-Grained Olivine-Bearing Gabbro

### Pieces 2-6E

Locally showing intense veining.

**COLOR:** Gray to greenish gray.
**LAYERING:** Not visible except for Piece 6E. This piece shows an inclined fine-grained band dipping at 55° that presumably represents a layer with a finer, primary grain size distribution.
**DEFORMATION:** None. However, small sheared bands are developed along the contacts of larger veins.
**PRIMARY MINERALOGY:**
Varies over section. Pieces 2, 3, and 4A are enriched in olivine and ilmenite.

Plagioclase—Mode: 55%-60%.
Crystal size: <0.5-30 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Partially replaced by albite in veined areas.

Clinopyroxene—Mode: 40%.
Crystal size: <0.5-30 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: Up to 5%.
Crystal size: <0.5-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Locally <2% by ilmenite.

**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Green amphibole partially rimming clinopyroxene (<10%). Olivine relatively fresh except for upper third of section, where it is partially replaced by yellowish material. Plagioclase partially replaced by albite(?) in more strongly veined portions. Some disseminated sulfides.
Percent vein material: Not determined.
Vein material: Green amphibole, albite and ilmenite.
Ilmenite veins only in Pieces 3 and 4A. Albite veins are up to 4 cm thick. Larger veins are along shear bands; green amphibole is always the first vein-filling mineral; white plagioclase fills the centers of the larger veins.

**118-735B-36R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1G**

**Coarse- to Medium-Grained Olivine-Bearing Gabbro**

**Pieces 1A-1G**

**COLOR:** Dark gray.

**LAYERING:** No clear layering, but variation in grain size; 3 mm average in top of Piece 1A; 6 mm average in bottom of Piece 1A; 10 mm in Pieces 1C and 1D; 20 mm in Pieces 1B, 1E, and 1F; and up to 40 mm in Piece 1G.

**DEFORMATION:** No deformation except sheared, amphibole vein in Pieces 1D and 1E.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%.
Crystal size: See layering.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Minor replacement by more sodic plagioclase.

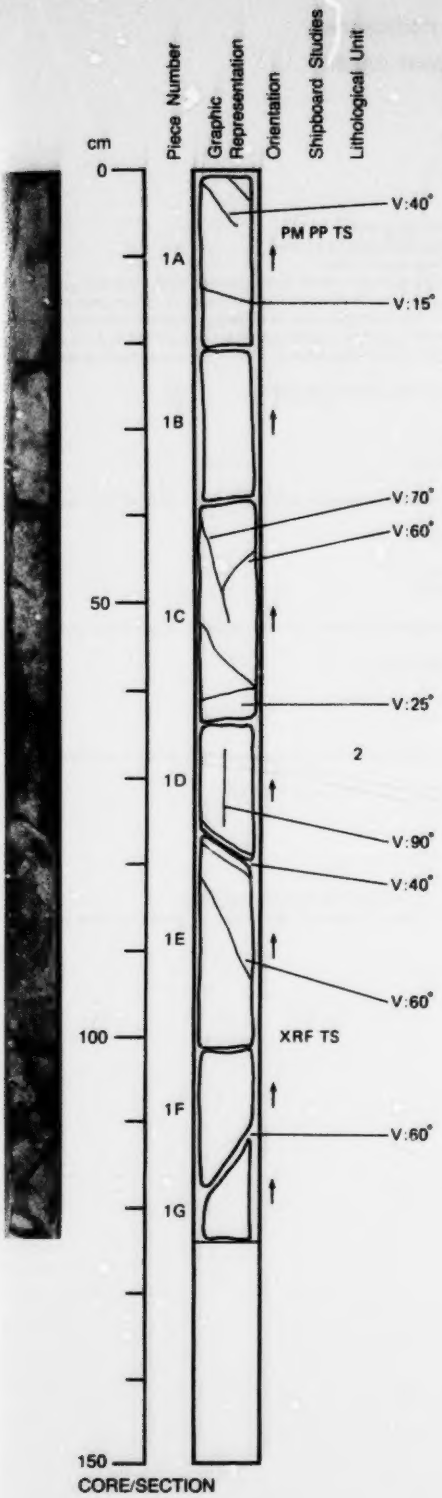
Clinopyroxene—Mode: 35%.
Crystal size: See layering.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replacement by amphibole.

Olivine—Mode: >5%.
Crystal size: See layering.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Replacement by amphibole and talc (?).

**SECONDARY MINERALOGY:**

Total percent: <30%.
Texture: Minor albitization of plagioclase and amphibolitization of clinopyroxene, especially in Piece 1C.
Percent vein material: <1%.
Vein material: Amphibole and "albite"-amphibole veins, sheared in Pieces 1D and 1E.

**COMMENTS:** The sheared amphibole vein in Pieces 1F and 1G bears striations dipping at 90°.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
1F
1G
V:40°
PM PP TS
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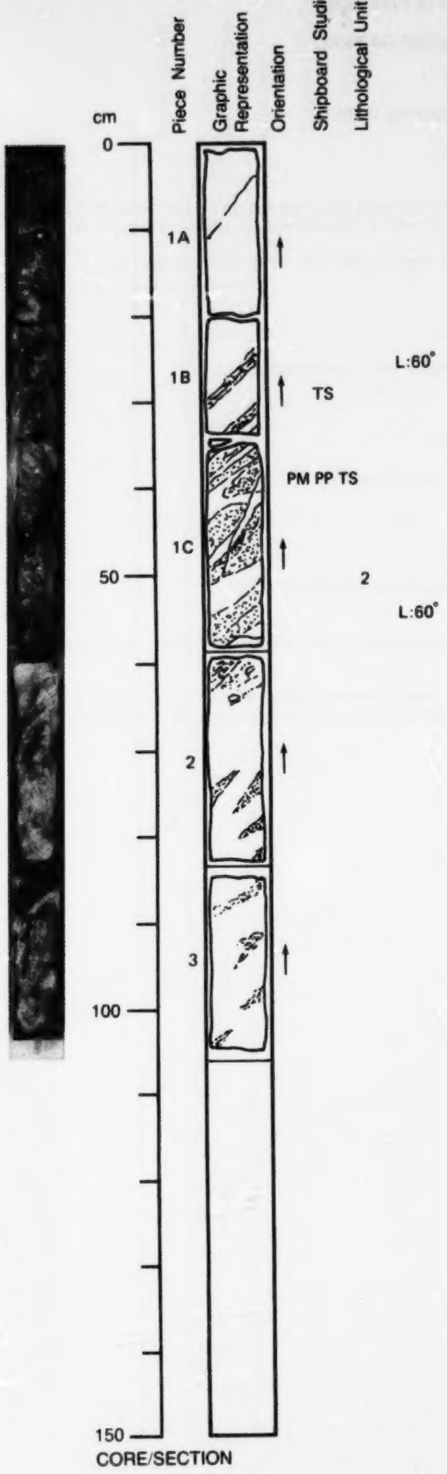
V:60°
XRF TS
V:60°
CORE/SECTION



**118-735B-36R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-3**

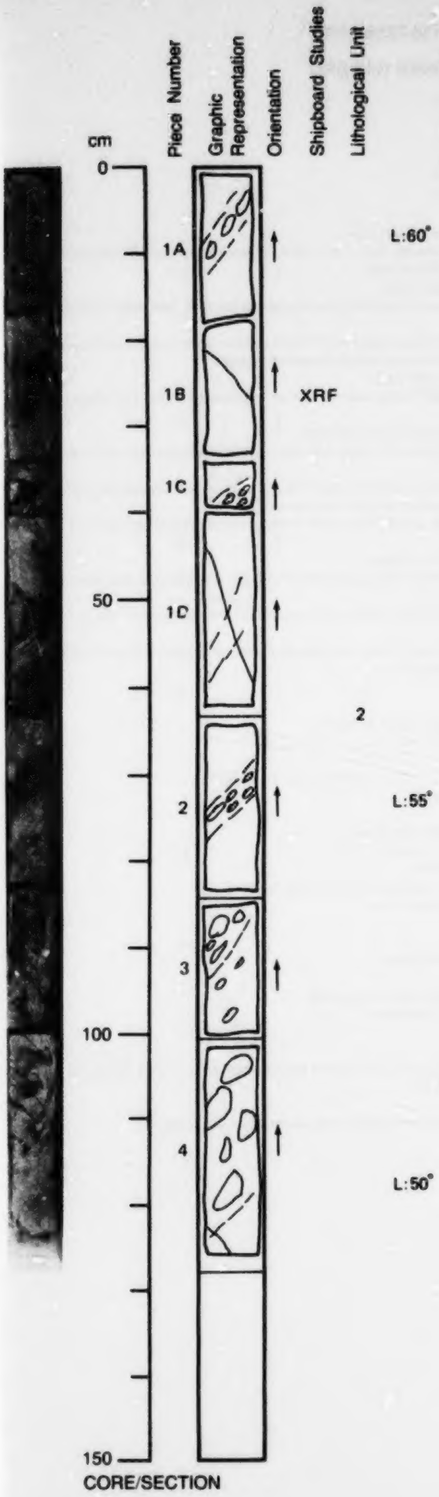
### Layered Olivine-Bearing Gabbro

**Pieces 1A-3**

**COLOR:** Dark gray.
**LAYERING:** Alternating layers of different grain size.
Average grain size of coarse-grained layers 10-20 mm.
Average grain size of fine grained layers 1 mm.
From the top to the bottom of the sections: 20 cm coarse-grained layer, 10-20 mm grain size 2-1 cm fine-grained layer 1 mm grain size; 2 cm coarse-grained layer, 10-15 mm grain size; 15 cm fine- to medium-grained layer <0.5-3 mm grain size, boundary is irregular; 1-2 cm coarse-grained layer, 5-10 mm grain size; 7 cm fine-grained layer, 0.5-1 mm grain size; 8 cm coarse-grained layer, 5-10 mm grain size; 30 cm alternation of medium-(5 mm) and coarse-grained (5-10 mm) layers.
Piece 3: Layer is not marked. The boundaries are irregular.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Variable <0.5-20 mm.
Crystal shape: Subhedral.
Preferred orientation: Shape preferred orientation defining foliation, which is not necessarily parallel to the layering.
Percent replacement: Almost none.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Variable <0.5-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Shape preferred orientation defining foliation, which is not necessarily parallel to the layering.
Percent replacement: 5% by amphibole.

Olivine—Mode: 3%-10%, locally concentrated.
Crystal size: Variable, <0.5-20 mm.
Crystal shape: Subhedral.
Preferred orientation: Shape preferred orientation defining foliation, which is not necessarily parallel to the layering.
Percent replacement: 50%-70% by clay and opaque minerals.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Not determined.
Percent vein material: Trace.
Vein material: Albite and amphibole.
**COMMENTS:** Fine-grained portions are equigranular microgabbro (Piece 1B).
Coarse-grained "layers" or veins are anorthositic in the center and lined with clinopyroxene.



**118-735B-36R-4**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-4**

**Layered Gabbro and Olivine Gabbro**

**Pieces 1A-4**

**COLOR:** Gray to dark gray, blotchy in coarse-grained rock.

**LAYERING:** Marked size and phase layering steeply inclined at 50°-60° to direction of core.

**DEFORMATION:** Fractures dip at 50°-60°—orthogonal to layering in Pieces 1B, 1D, and 4—are lined with green amphibole and white feldspar (albite?). Also, a faint internal foliation slightly oblique to primary layering, marked by tiny fractures lined with plagioclase and amphibole in Pieces 1A, 1D, and 4.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-60%.
Crystal size: Medium to coarse.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

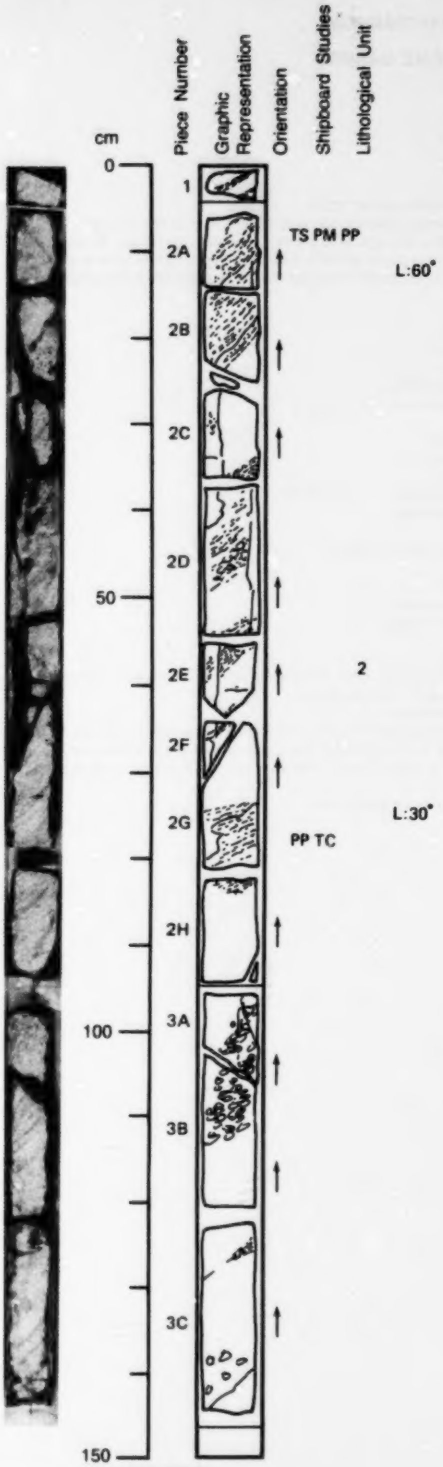
Clinopyroxene—Mode: 40%-60%.
Crystal size: Medium to coarse.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—5% in part of Piece 3; trace in Piece 2.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Green amphibole + feldspar in veins. Traces of amphibole + feldspar along minor microfractures + some ilmenite. No sulfide obvious.
Percent vein material: Not determined.

**COMMENTS:** Both plagioclase and clinopyroxene are cumulus phases in fine-grained pieces. Finer-grained portions are equigranular microgabbros. Especially coarse-grained pyroxene-rich cumulates in Pieces 1A, 1C, 2, 3, and 4. Piece 3 has abundant, 1 cm olivine crystals. Piece 4: Pyroxenes up to 6 cm.
Vein material: green amphibole + Na-plagioclase.



**118-735B-37R-1**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1-3C**

**Layered Olivine-Bearing Gabbro**

**Pieces 1-3C**

**COLOR:** Gray.

**LAYERING:** Alternating layers of different grain size.

from the top to the bottom of the section: 7 cm thick, alternation of fine- (1 mm) and coarse-grained (10 mm) (plagioclase-rich) layers;
9 cm thick, 0.5-2 mm grain size layers;
19 cm thick, alternation of fine- (1 mm) and coarse-grained (10 mm), irregular or discontinuous layers;
3 cm thick, clinopyroxene-rich, coarse-grained (10 mm) gabbro layer (almost a clinopyroxenite);
3 cm thick, coarse-grained (20-30 mm), plagioclase-rich layer;
3 cm thick, fine-grained (0.5-1 mm) layer;
15 cm thick, coarse-grained (20-30 mm) interval, rich in plagioclase at the top, irregular fine-grained part, interlayered;
9 cm thick, fine- to medium-grained (1-3 mm) layer;
18 cm thick, coarse-grained (10-20 mm) layer with clinopyroxene:plagioclase ratio of approximately 1:1;
7 cm thick, coarse- to medium-grained (3-10 mm) interval with clinopyroxene:plagioclase ratio of approximately 3:1, clinopyroxene-rich and olivine-rich layers;
14 cm thick, coarse-grained (10-15 mm) layer with clinopyroxene:plagioclase ratio of approximately 1:1, olivine-rich;
1 cm thick, fine-grained (0.5-1 mm) layer;
10 cm thick, coarse-grained (30-50 mm) plagioclase-rich layer with plagioclase:clinopyroxene ratio of 3:1;
7 cm thick, coarse-grained (20-50 mm) layer with plagioclase:clinopyroxene ratio of 1:1.

Foliation defined by elongate plagioclase, and clinopyroxene is roughly parallel to the layering that dips at 30°-60°, but mostly at 60°.

**DEFORMATION:** No deformation.

**PRIMARY MINERALOGY:**

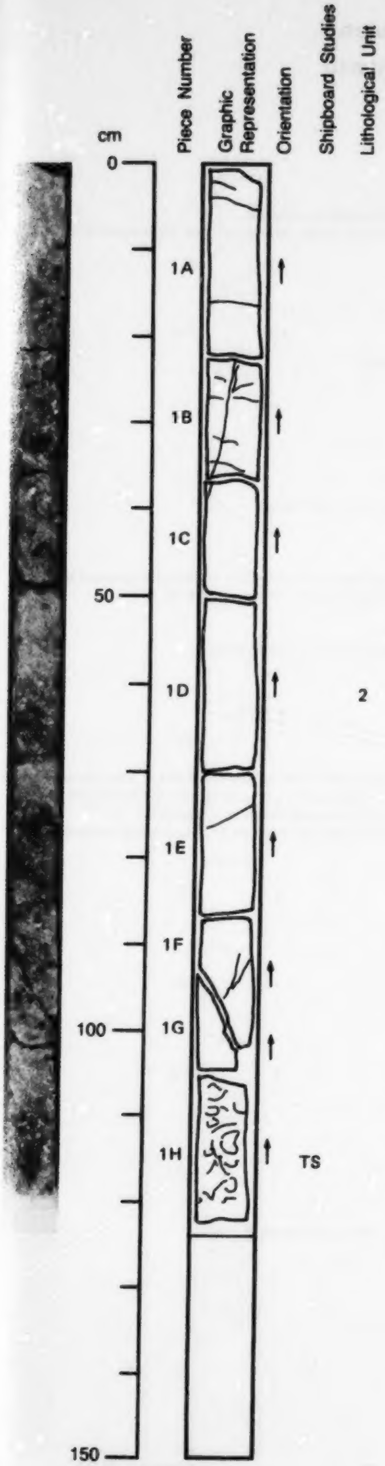
Plagioclase— Mode: Various; see layering above.
Crystal size: Various; see layering above.
Crystal shape: Euhedral.
Preferred orientation: Elongate roughly parallel to the layering.
Percent replacement: Almost none.

Clinopyroxene—Various; see layering above.
Crystal size: Various; see layering above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Elongate roughly parallel to the layering.
Percent replacement: <5% by amphibole.

Olivine—Mode: 3%-10%.
Crystal size: Various; see layering above.
Crystal shape: Subhedral.
Preferred orientation: Elongate parallel to layering.
Percent replacement: <5% by tremolite.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Clinopyroxene is slightly replaced by amphibole (total vol% <5%). Olivine is replaced by tremolite and is locally oxidized.
Percent vein material: Trace.
Vein material: Nearly vertical, 0.5-2 mm thick amphibole veins are present.



**118-735B-37R-2**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

**Pieces 1A-1H**

### Massive, Medium- to Coarse-Grained Olivine Gabbro

**Pieces 1A-1G**

**COLOR:** Medium gray.
**LAYERING:** Only weakly expressed, if at all. Two coarse-grained intervals occur at 19-24 and 97-104 cm. Average grain size is 1 cm; increasing to >2 cm at 97-104 cm.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 30 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: <5% by amphibole.

Olivine—Mode: 5%.
Crystal size: Up to 20 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Mostly fresh, but can be replaced.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Rock appears to be very fresh. Amphibole replacement of clinopyroxene <5%; olivine mostly unaltered but sometimes replaced. Minor sulfide dissemination.
Percent vein material: Not determined.
Vein material: Few veinlets with green amphibole + white mineral (albite?). Some ilmenite-filled veinlets + sulfides.

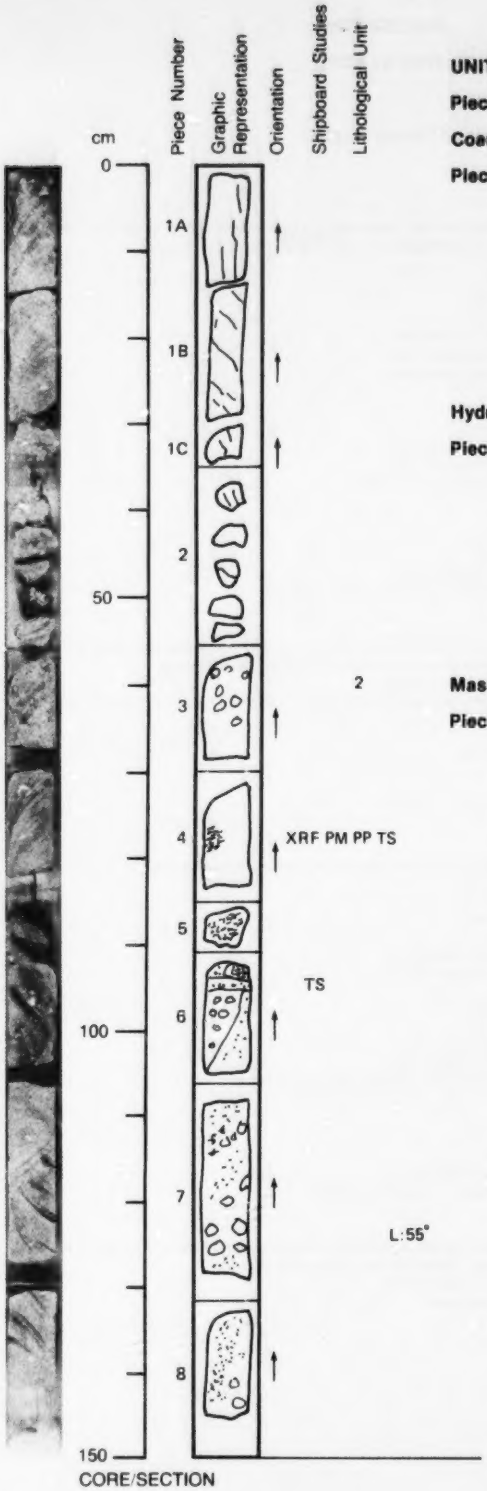
### Brecciated Olivine-Bearing Gabbro

**Piece 1H**

**COLOR:** Greenish-gray.
**LAYERING:** None.
**DEFORMATION:** Slight brecciation due to crushing of plagioclase and clinopyroxene.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 58%.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Up to 10% by green amphibole.

Olivine—Mode: 2%.
Crystal size: <10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to greenish mineral.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Green amphibole partially replacing clinopyroxene (rims) up to 10%. Some white (albite?) alteration mineral. Olivine altered to greenish product.
Percent vein material: Not determined.
Vein material: Green amphibole.



**118-735B-37R-3**

## UNIT 2: OLIVINE-BEARING AND OLIVINE GABBRO

### Pieces 1A-8

### Coarse-Grained Gabbro

### Pieces 1A-1C

**COLOR:** Gray to dark gray, mottled according to contrast in minerals.
**DEFORMATION:** Fractures veined with amphibole and albite, vertical in Piece 1A; inclined in Pieces 1B and 1C.
**LAYERING:** Not determined.
**PRIMARY MINERALOGY:** Not determined.
**SECOND MINERALOGY:**
Total percent: Moderate.
Texture: Not determined.
Percent vein material: Moderately fractured.
Vein material: Amphibole and albite.

### Hydrothermally Altered Gabbro

### Piece 2

**COLOR:** Greenish gray, green to white in veins.
**DEFORMATION:** Fracture/vein surfaces on most chunks of Piece 2.
**PRIMARY MINERALOGY:** Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole replaces most clinopyroxene. Cavity filling prismatic amphibole present. The rock has reddish-brown iron-oxyhydroxide stains. Olivine is altered.
Percent vein material: Not determined.
Vein material: Hornblende-albite.
**COMMENTS:** Comprises several chunks of hydrothermally altered gabbro.

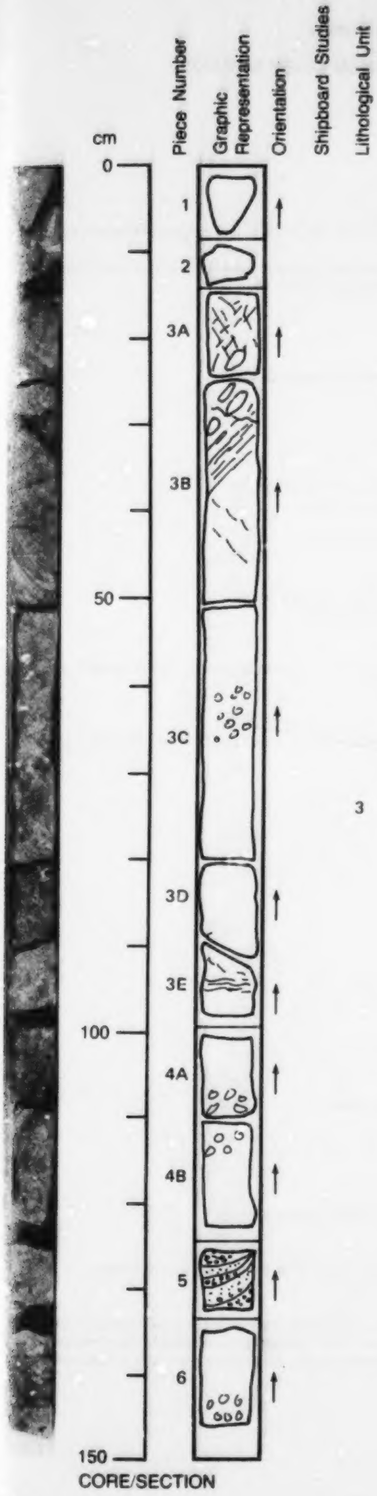
### Massive to Layered Gabbro

### Pieces 3-8

**COLOR:** Gray to dark gray.
**LAYERING:** Pieces 3-8: Highly inclined (approximately 60° from horizontal). Piece 7: Very coarse-grained zones. Piece 5: Very fine-grained diabase intrusion(?) with a horizontal contact at the top of Piece 6. May have overturned a layer in a soft crystal mush as it intruded.
**DEFORMATION:** A network of nearly horizontal fine fractures and two steeply dipping fractures in Piece 6.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Variable.

Clinopyroxene—Mode: 40%-60%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: Up to 5%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole and albite in veins, minor amphibole in rocks.
Percent vein material: Not determined.
Vein material: Amphibole and albite.



## 118-735B-38R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1-6

### Gabbro and Olivine Gabbro

### Pieces 1-6

**COLOR:** Gray to dark gray. Speckled according to mineralogy. Some yellowish gray where there is olivine. Minor greenish gray where amphibolitized.

**LAYERING:** Largely a sequence of fine- to coarse-grained layers with olivine concentrated at the base. Layer transitions not sharp, nor are inclinations either obvious or consistent. Dips steeper at top of section. Piece 5: Layering dips at 30°-60°; Three coarse-grained olivine layers alternating with fine-grained plagioclase-rich layers.

**DEFORMATION:** Pieces 3A and 3B: Two zones of foliation plus several orthogonal fractures. The zones are mylonitic and amphibolitized. The foliation crudely parallels layering lower in the section. Piece 3E: Narrow zone of horizontal foliation. Pieces 3A and 3B: Coarse mineral alignment parallels zones of foliation.

**PRIMARY MINERALOGY:**

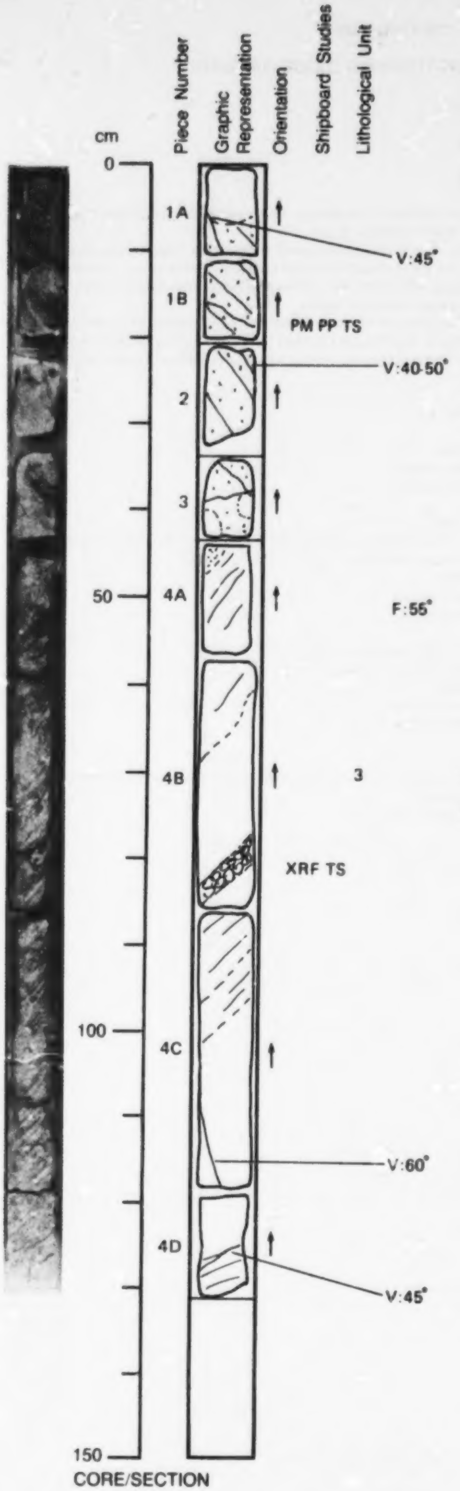
Plagioclase—Mode: 40%-60%.
Crystal size: <1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-60%.
Crystal size: 1-3 cm in part of Pieces 3C, 4A, 4B, 5, and 6. Up to 5 cm in coarse-grained zone of Pieces 3A and 3B, but generally less than 1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: Up to 5% in olivine-bearing zones.
Crystal size: Mostly 3-10 mm; 1 mm in Pieces 1 and 2.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Pieces 1, 2, and 3A: Green amphibole and albite. Traces of amphibole throughout and along minor fractures in the rock.
Percent vein material: Not determined.
Vein material: Amphibole.



**118-735B-38R-2**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-4D

### Layered Olivine Gabbro

### Pieces 1A (top) and 4A (bottom)-4D

**COLOR:** Dark gray with yellow patches (olivine).
**LAYERING:** Piece 4B: Compositional layering (olivine, plagioclase, and clinopyroxene enriched layers) dipping at 55°.
**DEFORMATION:** Piece 4D: Faint foliation. Pieces 4A-C: Foliation marked by olivine and clinopyroxene crystals is parallel to the layering and may be magmatic.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: <20 mm.
Crystal shape: Anhedral.
Preferred orientation: Marks faint foliation in Pieces 4A-4D.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-60%.
Crystal size: <20 mm.
Crystal shape: Anhedral.
Preferred orientation: Marks faint foliation in Pieces 4A-4D.
Percent replacement: Replacement by amphibole.

Olivine—Mode: 2%-10% in olivine-bearing zone.
Crystal size: <20 mm.
Crystal shape: Anhedral.
Preferred orientation: Marks faint foliation in Pieces 4A-4D.
Percent replacement: Replacement by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <15%.
Texture: Pseudomorphic amphibole after clinopyroxene and olivine. Minor albite(?). Piece 4D: Iron oxyhydroxides staining along vein.
Percent vein material: <1%.
Vein material: Amphibole.
**COMMENTS:** Piece 4B (near bottom): Coarse-grained clinopyroxene and olivine-rich layer 2 cm thick.

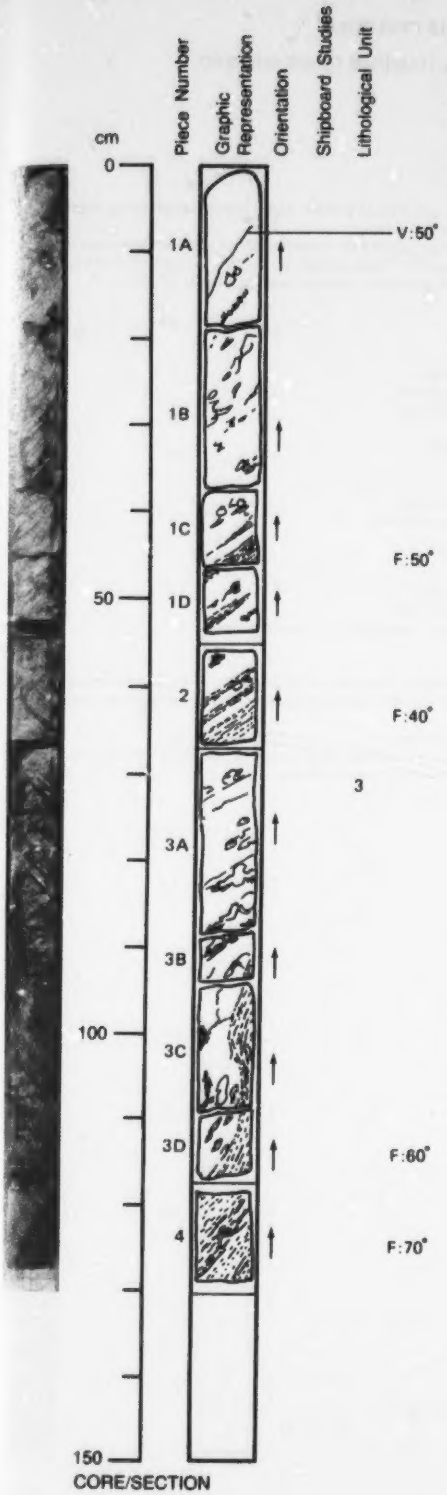
### Olivine Microgabbro Dike

### Pieces 1A (bottom)-4A (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-40%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Replaced by amphibole.

Olivine—Mode: 10%-20%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Replaced by amphibole and talc(?).
**SECONDARY MINERALOGY:**
Total percent: <30%.
Texture: Pseudomorphic amphiboles and talc(?) after clinopyroxene and olivine.
Percent vein material: <1%.
Vein material: Amphibole.
**COMMENTS:** Dike has a very marked contact dipping at 45° parallel to layering. Contact is best seen on round (cored) surface of Piece 3. Rock near contact is more altered than elsewhere. Dike texture is fine-grained subophitic. No phenocrysts. No obvious grain size differences across the dike.



## 118-735B-38R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-4**

## Layered Opaque and Olivine-Bearing Gabbro to Olivine Gabbro

**Pieces 1A-4**

**COLOR:** Gray, yellowish where olivine is present.

**LAYERING:** Size and modal layering.

Pieces 1A-1C: 30 cm thick, the bottom and top are plagioclase-rich (10-30 mm).
Pieces 1C-2: 20 cm thick, alternating fine- (1-3 mm) and coarse-grained (5-20 mm) layers.
Pieces 3A-3D: 30 cm thick, coarse-grained (10-40 mm).
Piece 3A: Includes a plagioclase-rich layer, 5 cm thick. The bottom half is clinopyroxene-rich.
Pieces 3C-3D: Foliation and layering very steep (nearly vertical).
Pieces 3C-4: >10 cm, fine-grained (3-6 mm), strongly foliated, olivine-rich.

**FOLIATION:** Clearly defined by elongate plagioclase, clinopyroxene, and olivine crystals, is generally parallel to the layer boundaries. Pieces 3B-4: Foliation in fine-grained part; layers show consistent change in inclination. Pieces 3A and 4: Olivine has the most markedly flattened shape. Pieces 3C, 3D, and 4: Fine-grained part shows remarkable magmatic foliation.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-70%.
Crystal size: Variable, see above.
Crystal shape: Subhedral.
Preferred orientation: Strong, parallel to the layering.
Percent replacement: Not determined.

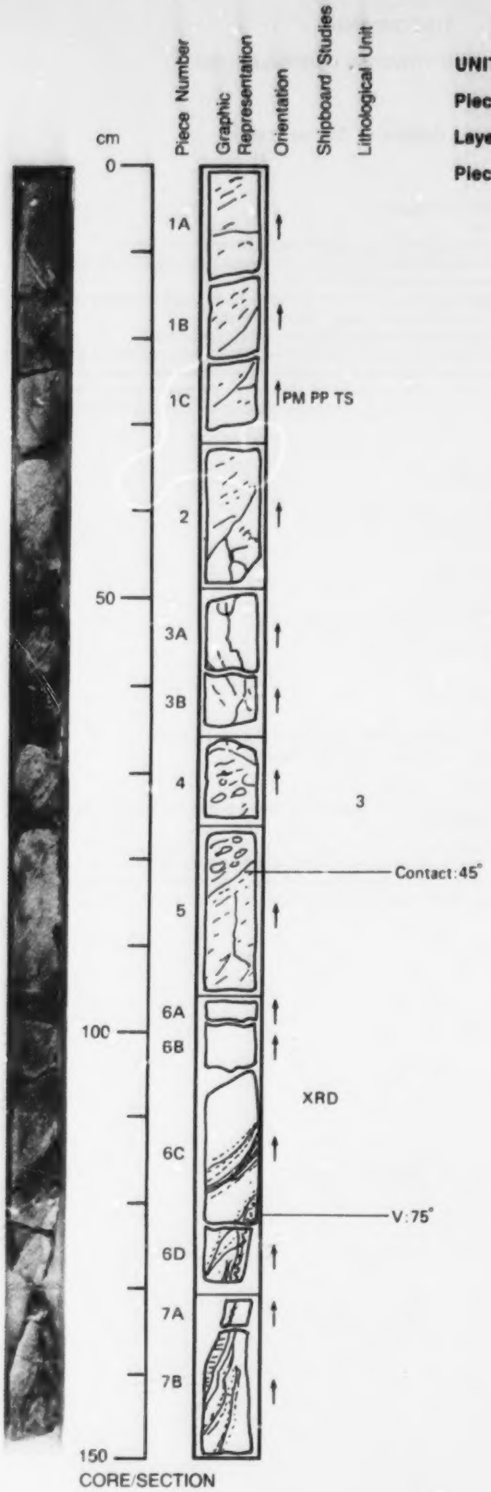
Clinopyroxene—Mode: 20%-50%.
Crystal size: Variable, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Strong, parallel to the layering.
Percent replacement: <3% by amphibole.

Olivine—Mode: 3%-8%.
Crystal size: Variable, see above.
Crystal shape: Anhedral.
Preferred orientation: Strong preferred orientation, especially in Piece 3A.
Percent replacement: <5% by tremolite with local oxidization.

**SECONDARY MINERALOGY:**

Total percent: <3%.
Texture: Olivine is locally oxidized and is replaced by tremolite from the margins. Amphibole replaces clinopyroxene (<3%).
Percent vein material: Trace
Vein material: Piece 1A: Thin (1 mm thick) amphibole vein dipping at 50°.

**COMMENTS:** Opaque mineral (ilmenite and magnetite) enrichment in pyroxene-rich layers (e.g., bottom of Piece 3A, and in Pieces 3B, 3C, and 3D), poor or absent in plagioclase-rich layers.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
PM PP TS
2
3A
3B
4
3
5
Contact:45°
6A
6B
XRD
6C
V:75°
6D
7A
7B
CORE/SECTION

**118-735B-38R-4**

**UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO**

**Pieces 1A-7B**

**Layered Olivine Gabbro**

**Pieces 1A-7B**

**COLOR:** Gray. Pieces 2 and 3: Greenish gray; Pieces 6 and 7: Green with brownish spots; Pieces 4 and 5: Yellowish gray in olivine enriched zones.

**LAYERING:** Grain size and phase layering in upper half of section. Grain size increases from fine- to medium-grained in Pieces 1 and 2 to coarse-grained (up to 3 cm) in upper third of Piece 5. Olivine enrichment parallel with grain size increase. Layering dips at 40°-50°.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

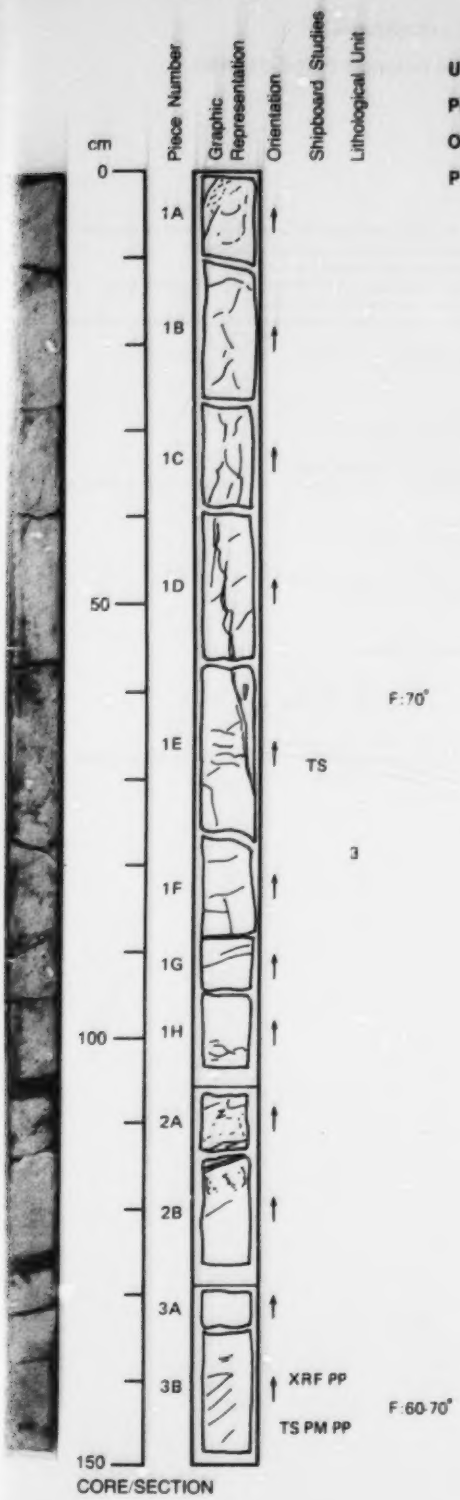
Plagioclase—Mode: 45%-65%.
Crystal size: Up to 30 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 30 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <5% by amphibole.

Olivine—Mode: <2% to 8%.
Crystal size: Up to 20 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by yellowish to brownish material.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Green amphibole and albite in Pieces 2, 3, and very top of Piece 4. Minor proportions of green amphibole throughout section, mostly along veins. Olivine replaced by yellowish to brownish material.
Percent vein material: Not determined.
Vein material: Pieces 6C-7B: up to 1 cm thick white-brownish carbonate vein. Intense oxidation with brown staining along this vein and satellite veins.



**118-735B-39R-1**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-3B**

**Olivine-Bearing to Olivine Gabbro**

**Pieces 1A-3B**

**COLOR:** Medium gray. Yellow gray where olivine is present (Pieces 1C, 1F, and 1G). Greenish gray along veins in upper half of section.

**LAYERING:** Phase layering and grain size layering. In general, decrease in grain size (except for the very top of Piece 1A, which is fine-grained) from very coarse-grained (Pieces 1A, 1B, and 1C) with plagioclase up to 5 cm over coarse-grained (Pieces 1D-1G) to medium-grained (Pieces 1H-3B) with average grain size 0.5 cm from the top to the bottom of the section. Olivine enrichment in the interval from 57-94 cm.

**DEFORMATION:** Weak. Weak foliation visible in Pieces 2B, 3A, and 3B, inclined at 60°-70°.

**PRIMARY MINERALOGY:**

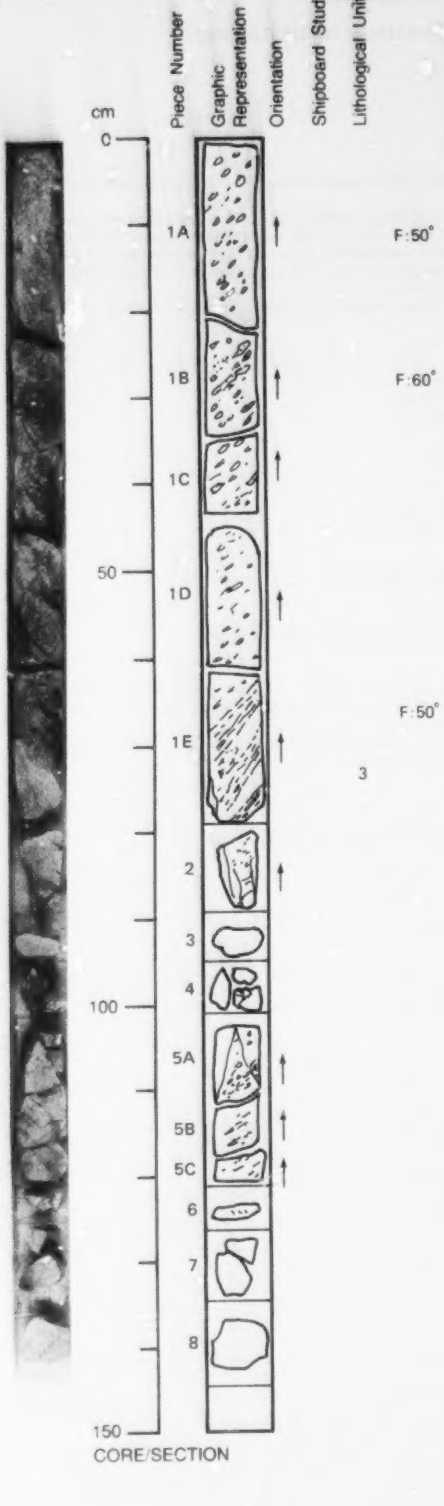
Plagioclase—Mode: 45%-70%.
Crystal size: Up to 5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-45%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: <2%-10%.
Crystal size: Up to 2 cm (in coarse-grained zone).
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partially replaced by yellowish-brown mineral.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Occasional minor clinopyroxene replacement by green amphibole. Some amphibole alteration along veins. Olivine partially replaced by yellowish brown material. Few sulfides.
Percent vein material: Not determined.
Vein material: Green amphibole plus white mineral (albite?) in veins and veinlets in upper half of section. Pieces 2A and 2B: Carbonate(?) vein with oxidation rim.



## 118-735B-39R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-8**

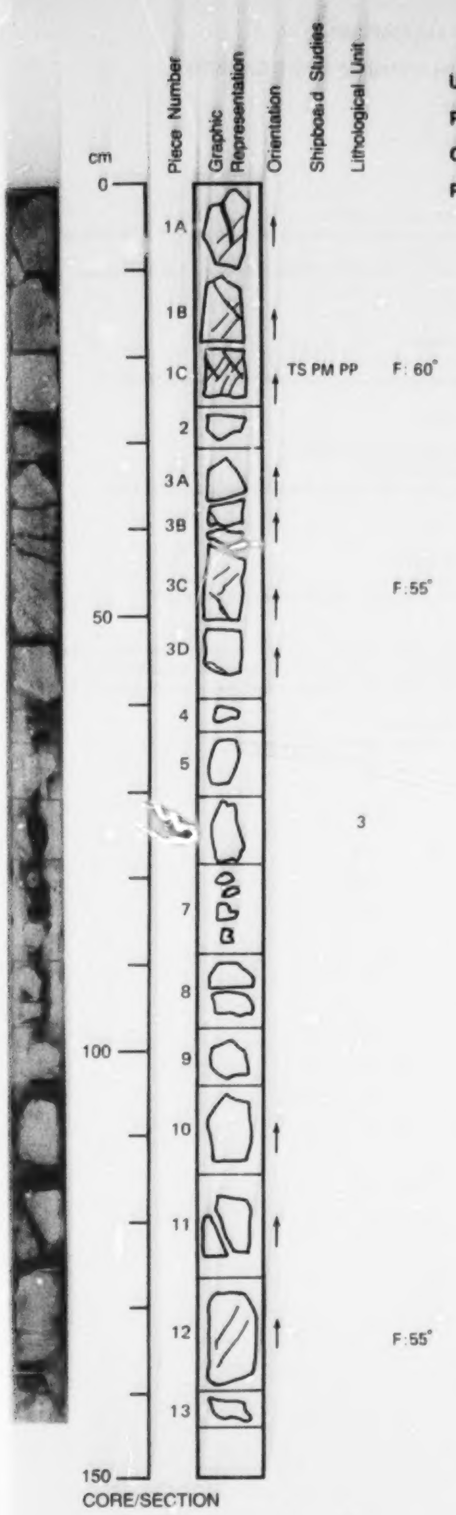
**Olivine-Bearing Gabbro**

**Pieces 1A-8**

**COLOR:** Dark gray, gray.
**LAYERING:** Size and modal layering. Foliation parallel to the layering is defined by elongate plagioclase, clinopyroxene, and olivine grains. Inclination is 50°-60°.
Pieces 1A and 1B: 20 cm thick, medium-grained (3-6 mm) layer.
Pieces 1B and 1C: 7 cm thick, coarse-grained (10-30 mm), plagioclase-rich layer.
Pieces 1C-1E: 13 cm thick, medium-grained (5-10 mm) layer.
Piece 1E: 10 cm thick, fine-grained (0.5 mm) to medium-grained (3mm) layer, olivine-rich near the bottom.
Pieces 2-8: Medium-grained (1-3 mm).
**DEFORMATION:** Almost none.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-70%.
Crystal size: Various depending on layers.
Crystal shape: Subhedral.
Preferred orientation: Strong, parallel to the layering.
Percent replacement: None in Piece 1, but moderate in Pieces 2-8 by sodium-rich plagioclase.

Clinopyroxene—Mode: 20%-35%.
Crystal size: Various depending on layers.
Crystal shape: Anhedral.
Preferred orientation: Strong, parallel to the layering.
Percent replacement: <5%-20% by amphibole.

Olivine—Mode: 2%-4%.
Crystal size: Various, depending on layers.
Crystal shape: Anhedral.
Preferred orientation: Strong, parallel to the layering.
Percent replacement: Pieces 2-8 are strongly oxidized.
**SECONDARY MINERALOGY:**
Total percent: Pieces 1A-1E; <5%, Pieces 2-8; >20%.
Texture: Pieces 2-8: Fairly amphibolitized (amphibole 20%) and veined by amphibole. Pieces 1A-1E very fresh (amphibole 5%). Olivine strongly oxidized.
Percent vein material: Not determined.
Vein material: Amphibole


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1A
1B
1C
TS PM PP
F: 60°
2
3A
3B
3C
F:55°
50
3D
4
5
3
7
8
100
9
10
11
12
F:55°
13
150
CORE/SECTION

## 118-735B-39R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-13

### Olivine Microgabbro

### Pieces 1A-13

**COLOR:** Light gray.

**LAYERING:** Igneous lamination defined by aligned plagioclase and olivine dipping at 55°-60°. Texture is equigranular.

**DEFORMATION:** Minor granulation near veins. Piece 5 is weakly foliated with stretched pyroxene and plagioclase and is partially recrystallized.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 65%.
Crystal size: 0.5-1 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Possible alteration to sodic plagioclase around fractures.

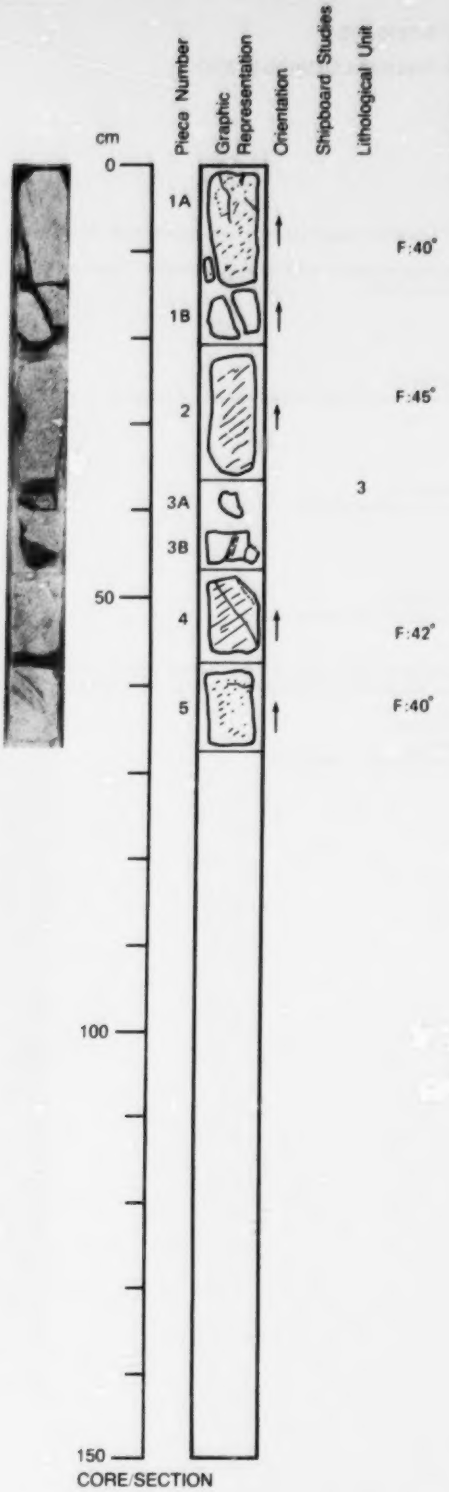
Clinopyroxene—Mode: 25%.
Crystal size: 0.5-1 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Replaced by green amphibole.

Olivine—Mode: 10%
Crystal size: 0.5-1 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by tremolite-actinolite.

**SECONDARY MINERALOGY:**

Total percent: 15%-30%.
Texture: Green amphibole replacing clinopyroxene and filling fractures. Olivine is partly replaced by tremolite-actinolite. Plagioclase is milky around fractures due to granulation and possible alteration to sodic plagioclase.
Percent vein material: Not determined.
Vein material: Green amphibole.

**COMMENTS:** Fractures and veins normal to igneous lamination.



### 118-735B-39R-4

### UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-5**

**Feebly Foliated Olivine Gabbro**

**Pieces 1A-15**

**COLOR:** Gray with orange-red alteration areas of olivine.

**LAYERING:** Obscured by foliation, probably some original coarse-fine grain size variations. Medium- to fine-grained transition in Piece 1A.

**DEFORMATION:** Weak to moderate foliation. Defined by elongate pyroxene and plagioclase.

**PRIMARY MINERALOGY:**

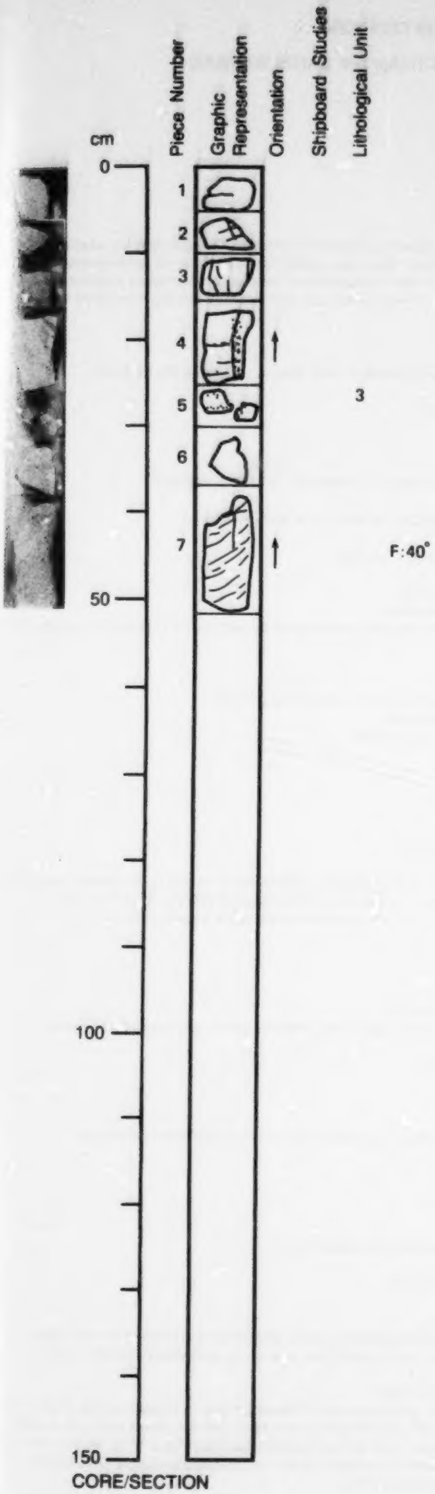
Plagioclase—Mode: 50%-55%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral, fractured.
Preferred orientation: Elongate in foliation.
Percent replacement: Whitish alteration along veins and fractures (albite/clays?).

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral, angular to elongate grains.
Preferred orientation: Elongate in foliation.
Percent replacement: Locally altered to amphiboles along veins and fractures.

Olivine—Mode: 2%-7%.
Crystal size: 2-9 mm.
Crystal shape: Elongate, anhedral.
Preferred orientation: Not determined.
Percent replacement: Variously altered to orange-brown pseudomorphs.

**SECONDARY MINERALOGY:**

Total percent: 10%-20%.
Texture: Partial replacement of olivine Pieces 1, 4, and 5: Actinolitic amphibole along fractures; brownish clay minerals on fracture surfaces. Some whitish alteration of plagioclase(?); Piece 1B: Coarse slickensided surface with clay minerals, chlorite, amphibole, and talc(?) on surfaces.
Percent vein material: Not determined.
Vein material: Clay minerals, chlorite, amphibole, and talc(?).



## 118-735B-40R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1-7**

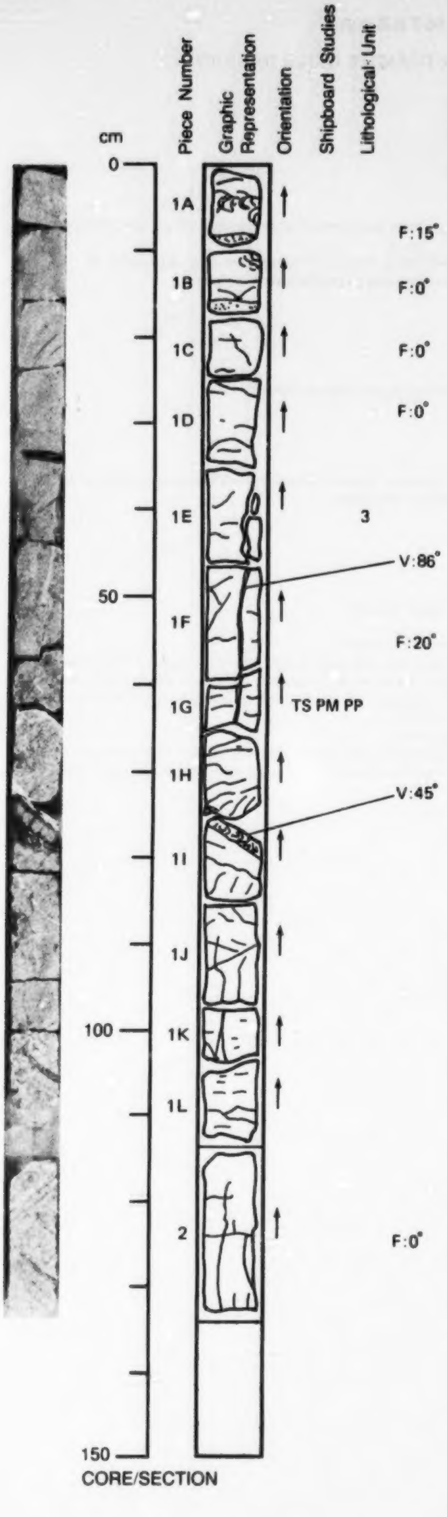
**Olivine Gabbro**

**Pieces 1-7**

**COLOR:** Gray, locally stained orange.
**LAYERING:** No obvious primary layering—there are zones of concentrated olivine, but difficult to determine if primary layering.
**DEFORMATION:** Pieces 1-6: Massive, unfoliated. Piece 7: Foliated, defined by elongation of clinopyroxene, probably in a porphyroclastic plagioclase matrix.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50%-100% by predominantly albite(?).

Clinopyroxene—Mode: 42%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Pieces 1-6, None. Piece 7: Clinopyroxene elongate in plane of foliation.
Percent replacement: 90%-100% by amphibole.

Olivine—Mode: 0%-30%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 90% by oxide mineral.
**SECONDARY MINERALOGY:**
Total percent: Alteration moderate to extensive.
Texture: Clinopyroxene is almost totally replaced by amphibole throughout. Plagioclase is predominantly altered to albite(?), milky white in appearance, and locally stained orangish-brown by iron oxides throughout section. Olivines altered to orangish oxide mineral. No oikocrysts or coarse-grained textures.
Percent vein material: Not determined.
Vein material: Green amphibole and/or sodic plagioclase. Pieces 1-7: Thin veins filled by amphibole. Pieces 4-6: Slightly thicker veins (1-3 mm wide) have concentration of white (+ staining) feldspar.



### 118-735B-40R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-2

### Mylonitic Metagabbro

### Pieces 1A-1D

**COLOR:** Light gray.
**LAYERING:** None apparent.
**DEFORMATION:** Intense. Foliation is defined by preferred orientation of augen and the nearly complet recrystallization of previous grains. Grain size varies from 1 to 7 mm for porphyroclasts and <1 mm for the matrix. Piece 1A has millimeter-thick banding of alternating plagioclase and mafic minerals. The foliation in turn is folded and even refolded into tight isoclinal folds.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 68%-69%.
Crystal size: <1-4 mm.
Crystal shape: Elongated as small bands or lens shapes parallel to the foliation.
Preferred orientation: Strong.
Percent replacement: Unaltered.

Clinopyroxene—Mode: 30%.
Crystal size: 1-7 mm.
Crystal shape: Stretched augen that are rotated into the foliation plane.
Preferred orientation: Strong.
Percent replacement: Partly replaced by amphibole and oxidized.

Olivine—Mode: 1%-2% (especially Piece 1D).
Crystal size: Up to 2 mm.
Crystal shape: Irregular to rounded.
Preferred orientation: Not determined.
Percent replacement: Strong to complete replacement by serpentine or chlorite + magnetite with rims of talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Late fractures are filled by amphibole and plagioclase.
Percent vein material: Not determined
Vein material: Amphibole and plagioclase.

### Porphyroclastic Metagabbro

### Pieces 1E-1J, and 1L-2

**COLOR:** Light greenish gray to yellow brown.
**LAYERING:** None apparent.
**DEFORMATION:** Defined by deformation and elongation of clinopyroxene and plagioclase, and by the recrystallization of plagioclase as neoblasts into the foliation planes. Grain size for plagioclase varies from 1 cm to <1 mm and for clinopyroxene from 1.5 cm to 3 mm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-10 mm.
Crystal shape: Lens.
Preferred orientation: Not determined.
Percent replacement: Can be partly replaced by prehnite and cut by amphibole veinlets.

Clinopyroxene—Mode: 38%-39%.
Crystal size: 3-15 mm.
Crystal shape: Lens.
Preferred orientation: Strong.
Percent replacement: 50% by green amphibole with rims of dark green amphibole.

Orthopyroxene—Mode: Trace.
Crystal size: Not determined.
Crystal shape: Blade-lens.
Preferred orientation: Strong.
Percent replacement: Totally replaced by amphibole.

Ilmenite—Mode: 1%-2% (in Piece 2)
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene is largely replaced by green amphibole and rimmed by dark green amphibole. Plagioclase can be partly prehnitized and cut by amphibole veinlets. Trace of sulfides in Piece 2.
Percent vein material: Not determined.
Vein material: Amphibole, talc, and plagioclase. Pieces 1H and 1I: Contain single plagioclase vein, 8 mm across with 10%-20% amphibole and possible prehnite. Some fractures in other pieces (flat to 45° dip) are similar. Subvertical fractures run from Piece 1F to 1K and cut all th structures. They are filled by green amphibole (70%) and plagioclase (30%). One fracture is filled by green talc (slippery, soapy touch).

## 118-735B-40R-2 (continued)

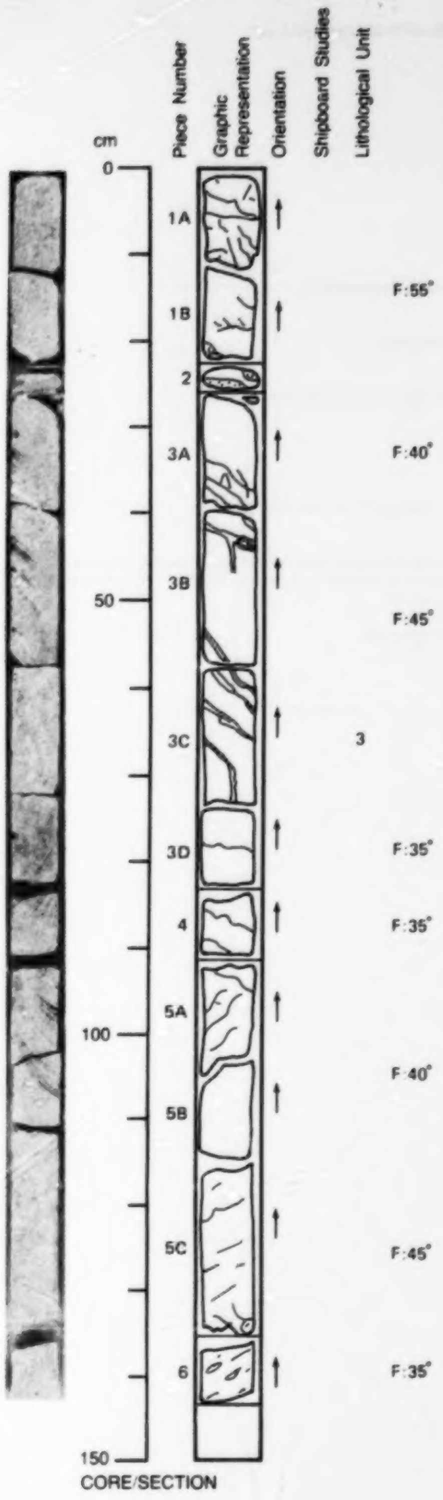
### Massive Gabbro

### Piece 1K

**COLOR:** Brownish green.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: 50%.
  Crystal size: 1-5 mm.
  Crystal shape: Euhedral.
  Preferred orientation: None.
  Percent replacement: Slight, invaded by amphibole.

  Clinopyroxene—Mode: 50%.
  Crystal size: 1-7 mm (up to 6-7 cm long).
  Crystal shape: Interstitial.
  Preferred orientation: None.
  Percent replacement: Moderate replacement by amphibole.

  Orthopyroxene—Mode: Trace.
  Crystal size: 1-3 mm.
  Crystal shape: Interstitial.
  Preferred orientation: None.
  Percent replacement: Complete replacement by amphibole.
**SECONDARY MINERALOGY:**
  Total percent: <35%.
  Texture: Pyroxenes are replaced by light green (pseudomorphs) and dark green (rims) amphiboles. Plagioclase is invaded by amphibole. A fracture 1-2 mm thick is filled by green amphibole and accessory plagioclase.
  Percent vein material: Not determined.
  Vein material: Amphibole and plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3A
3B
3C
3D
4
5A
5B
5C
6
3
F:55°
F:40°
F:45°
F:35°
F:35°
F:40°
F:45°
F:35°
CORE/SECTION

## 118-735B-40R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-6**

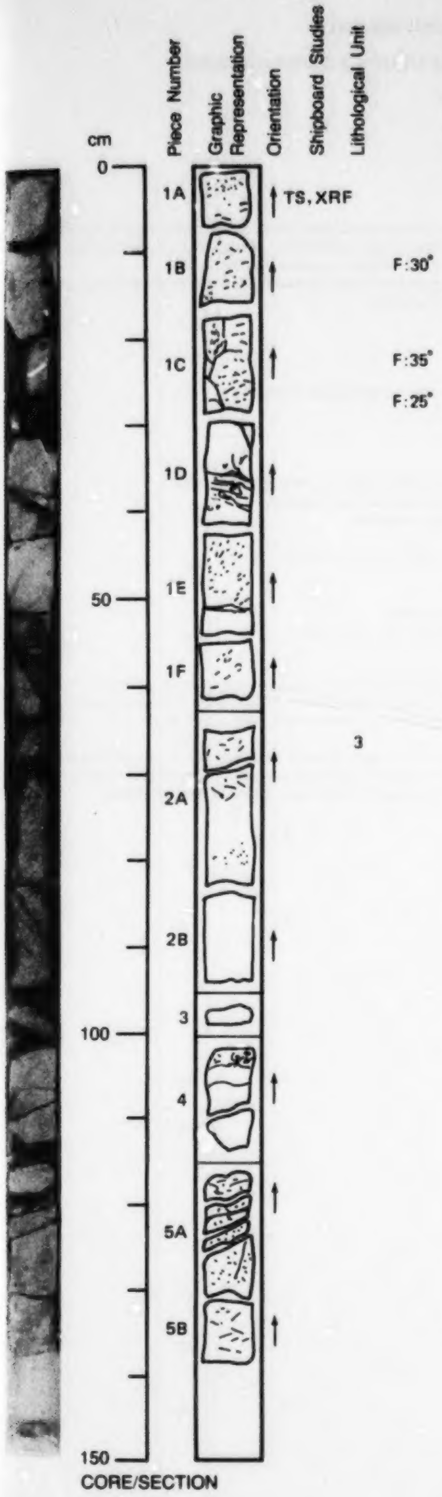
### Foliated to Poorly Foliated Metagabbro

**Pieces 1A-6**

**COLOR:** Green to grayish green.
**LAYERING:** None apparent. Grain size variation: Piece 6 could contain a layer contact.
**DEFORMATION:** Defined by stretching of pyroxene and plagioclase. Pyroxene and plagioclase reach 7 to 15 mm in length.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 7-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%.
Crystal size: 7-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight, by green amphibole.

Orthopyroxene—Mode: <2% (very sporadic).
Crystal size: <3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight, by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Green amphibole replacing pyroxene (pseudomorphs), or dark green amphibole rimming or crystallized along cleavages. Pieces 3A, 3C, 5G, and 6 contain pyrite. In Piece 6, pyrite is widespread, elsewhere it is associated with green amphibole or associated with chlorites in fractures (Pieces 5A and 5B).
Percent vein material: Not determined.
Vein material: Pyrite, chlorite, amphibole, and plagioclase. Veins up to 1 cm thick are filled mainly by plagioclase + green amphibole. Fractures of late-stage type are filled by green amphiboles with accessory plagioclase (30%).
A yellow green mineral could be epidote(?). Pieces 1A, 1B, 2, and 3B: Fractures have slickensided amphiboles and chlorite.



## 118-735B-40R-4

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-5B

### Olivine-Bearing Gabbro

### Pieces 1A-5B

**COLOR:** Gray to white-green along deformed zone.

**LAYERING:** Distinct size variations occur as follows: Pieces 1A to 1C, fine-grained at top, coarse-grained at bottom; Pieces 1E to 2A, fine-grained at top, coarse-grained at bottom; and Pieces 5A to 5B, fine-grained at top, coarse-grained at bottom. These variations are only the most obvious. The changes can be rather sharp, as in Pieces 1E, 1F, and 2A. The changes are not always planar; they can be rather irregular and patchy. Contacts generally dip at 30°-35° to the left. Olivine is irregularly distributed; concentrations occur at 35, 70, 105 and 120 cm. Distribution is even in Piece 5.

**DEFORMATION:** Piece 1: Distinct foliation dipping at 30°-35° to the left is prominent. This may have been partly an original lamination, as in Section 118-735B-40R-5. Piece 1D: A shear zone cuts the foliation; the rock is brecciated. Numerous brittle fractures, subhorizontal to near-vertical, are common; some are coated with a soft talclike mineral, although many are empty. A deformed zone contains big milky plagioclase.

**PRIMARY MINERALOGY:**

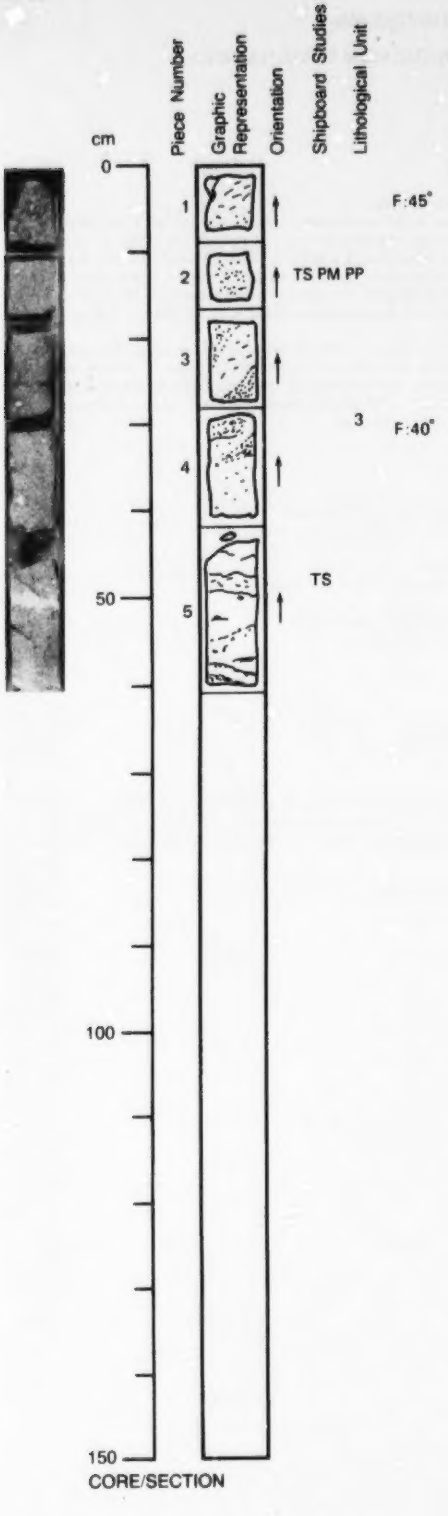
Plagioclase—Mode: 50%-60%.
Crystal size: 1-9 mm.
Crystal shape: Anhedral.
Preferred orientation: May be an igneous lamination.
Percent replacement: Some sodic plagioclase along shear zones.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1-9 mm, particularly coarse at 72 and 138 cm.
Crystal shape: Anhedral.
Preferred orientation: May be an igneous lamination.
Percent replacement: 5%-10% by amphibole.

Olivine—Mode: 0%-5%.
Crystal size: 0.5-4 mm
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 30% by talc-tremolite.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Amphibole after clincpyroxene, particularly in vertical lenses at 15-25 cm associated with vertical fracture. Amphibole and talc/serpentine(?) along some fracture surfaces. Some albitization of plagioclase in shear zones. Pyrite (<1 mm) as a trace throughout the section, not restricted to fractures.
Percent vein material: 5%.
Vein material: Amphibole in some areas.



**118-735B-40R-5**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1-5**

### Olivine-Bearing Gabbro

**Pieces 1-5**

**COLOR:** Gray.

**LAYERING:** Defined by medium- to fine-grained transitions. These occur most clearly in Pieces 1, 3, and 4. The medium-grained sections have a distinct lamination that may be igneous. Coarse- to fine-grained transitions dip at 45°. Piece 1: Lamination dips at 25°.

**DEFORMATION:** Only evidence is the above-mentioned lamination. If the lamination is not igneous, then it results from a slight deformation.

**PRIMARY MINERALOGY:**

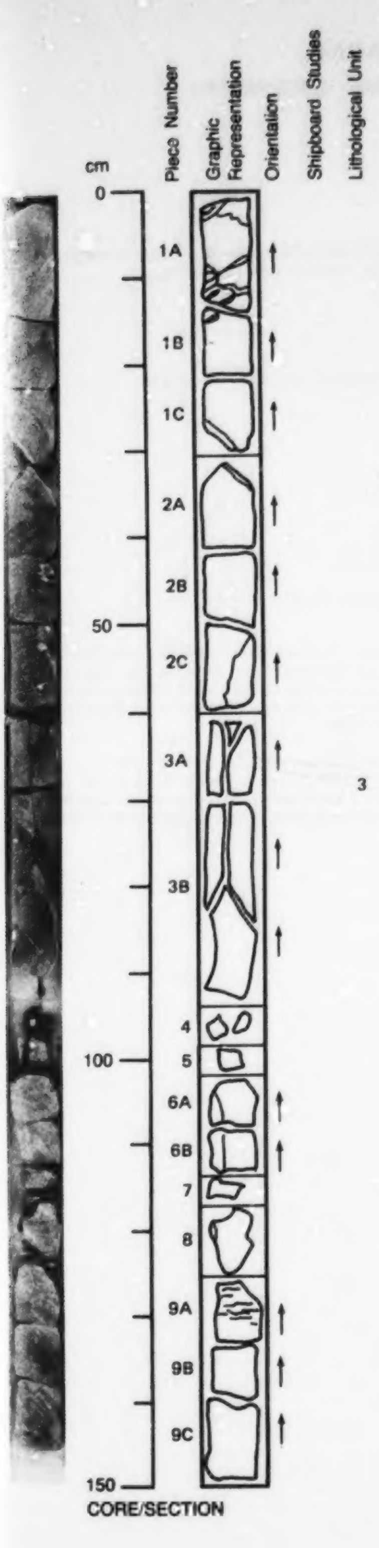
Plagioclase—Mode: 55%-60%.
Crystal size: 0.5-9 mm.
Crystal shape: Anhedral.
Preferred orientation: Define a distinct elongation in Piece 1.
Percent replacement: Fresh.

Clinopyroxene—Mode: 40%.
Crystal size: 0.5-9 mm.
Crystal shape: Anhedral to subhedral; generally interstitial; few ophitic.
Preferred orientation: Aligned along magmatic foliation.
Percent replacement: 2%-3% by amphibole.

Olivine—Mode: 0%-5%; An olivine-rich band occurs at 55 cm.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 10%-20% by talc-actinolite.

**SECONDARY MINERALOGY:**

Total percent: 5%.
Texture: Olivine is replaced by talc-actinolite. Green, soft, talc-serpentine occur on fracture surfaces. Most of the section is fresh. Fine pyrite is disseminated throughout most of the section. Piece 5: Some amphibole after pyroxene along feldspathic vein.
Percent vein material: 5%.
Vein material: Feldspathic, up to 2 cm wide. Piece 5: One large (10-15 mm) and several small (1-2 mm) feldspathic veins cut this piece. The large vein cuts the lamination and dips into the core at 45°, plunging down the centerline of the core. Smaller veins are similar.



**118-735B-41R-1**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-9C

### Gabbro

### Pieces 1A-3A, 9B, and 9C

**COLOR:** Gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Weakly penetrative foliation inclined at 45°, defined by stretched pyroxene.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 1-3 mm.
Crystal shape: Subhedral granular.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 0.5-5 mm.
Crystal shape: Subhedral granular.
Preferred orientation: Elongated parallel to foliation.
Percent replacement: Partially replaced by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Principle alteration consists of rimming and partial replacement of pyroxene by amphibole and a few late <1 mm thick amphibole veins.
Percent vein material: 1%.
Vein material: Amphibole and plagioclase. Pieces 1A-2A: Feldspar-rich veins, containing minor amphibole, are typically 2-3 mm thick.
**COMMENTS:** Medium-grained, subhedral. Grain size graded from top of section (pyroxene crystals, 1-5 mm) downward to 70 cm (average grain size about 0.5-3.5 mm).

### Olivine Gabbro

### Pieces 3B-8

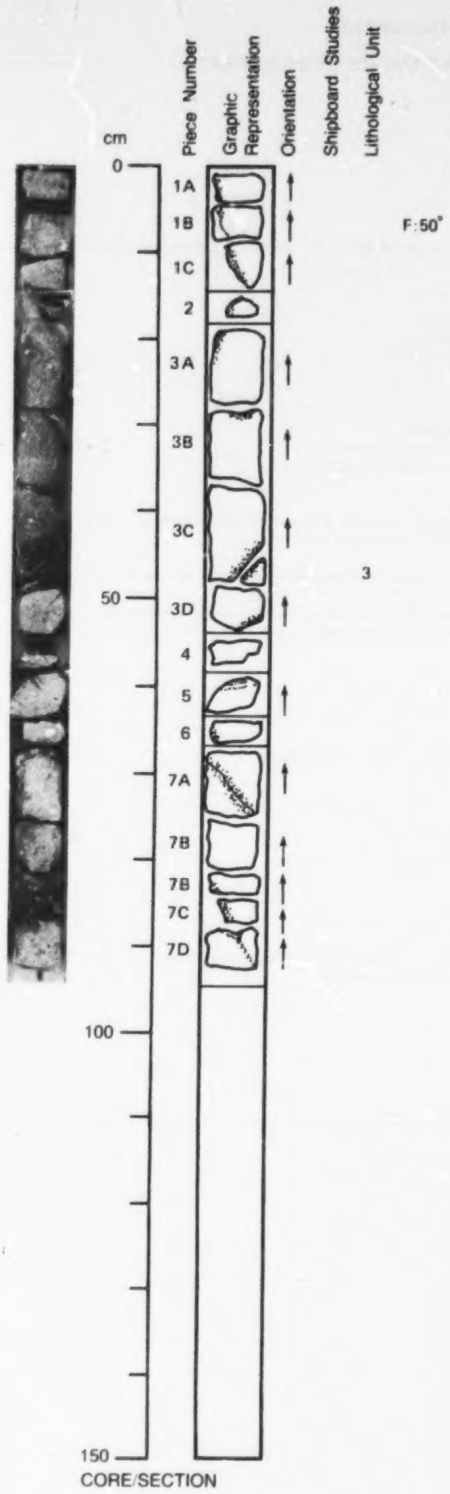
**PRIMARY MINERALOGY:**
Similar to gabbro described above except for the presence of olivine.

Olivine—Mode: 1%-5%.
Crystal size: Up to 6 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pieces 4-8: More oxidized.
Percent vein material: Not determined.
Vein material: Amphibole and plagioclase. Pieces 5 and 8: Plagioclase-rich vein is stained yellow, suggesting former presence of sulfides.

### Amphibolitized Gabbro Gneiss

### Piece 9A (126-129 cm)

**COLOR:** Gray.
**LAYERING:** No primary igneous layering.
**DEFORMATION:** Foliation defined by elongation and stretching of medium-grained pyroxene and plagioclase crystals.
**PRIMARY MINERALOGY:** Similar to gabbro above.
**SECONDARY MINERALOGY:** Similar to gabbro above.



**118-735B-41R-2**

**UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO**

**Pieces 1A-7D**

**Olivine Metagabbro**

**Pieces 1A-7D**

**COLOR:** Gray.
**LAYERING:** Some grain-size variation; Pieces 3A-3C and 7A-7B: Alternating medium- to coarse-grained.
**DEFORMATION:** Possible foliation, but may be due to primary grain-size layering.
**PRIMARY MINERALOGY:**

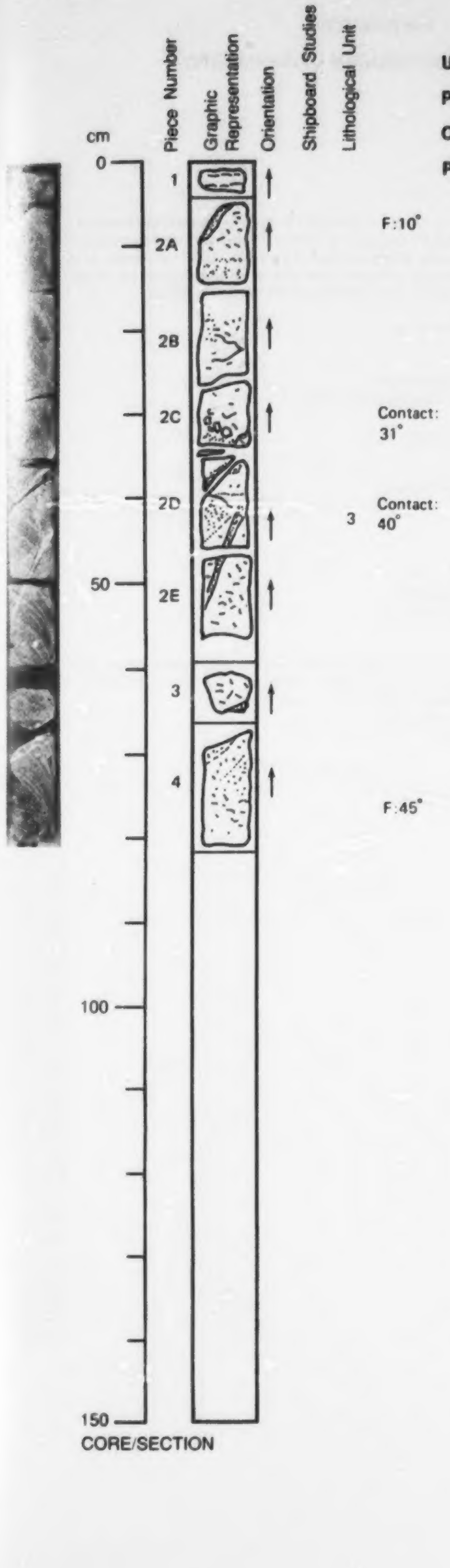
Plagioclase—Mode: 50%-55%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to slight alteration to milky white feldspar.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 90% by amphibole.

Olivine—Mode: 0%-10%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent alteration: 100% by black, white, and iron oxide minerals.

**SECONDARY MINERALOGY:**

Total percent: Moderate to extensive.
Texture: Plagioclase is partially recrystallized to neoblasts, and partially altered to milky white feldspar, locally stained by iron oxides. Clinopyroxene is 90% altered to amphibole. Olivine is altered to a black, meshlike mineral and is filled by a whitish mineral, probably talc, or colorless amphibole in Piece 1A. Elsewhere, olivine is altered to orange iron oxides. Piece 7D: Trace of sulfides and concentrations of ilmenite.
Percent vein material: Not determined.
Vein material: Sodic plagioclase, chlorite, carbonate, actinolite, and iron oxides.
Piece 1: Vein filled by carbonate and green mineral, possibly chlorite. Piece 3A: Vein filled by albite, actinolite, and carbonate. Piece 3C: Fracture surface coated by chlorite and stained by iron oxides. Pieces 7A, 7C, and 7D: Veins filled by albite, actinolite, and stained by iron oxides plus some chlorite.



### 118-735B-41R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1-4

### Olivine-Bearing Gabbro and Olivine Gabbro

### Pieces 1-4

**COLOR:** Gray, white to green-white along veins.

**LAYERING:** Layers defined by grain-size variations on various scales (4-20 cm); Pieces 2A-2C (30 cm), fine-grained top, coarse-grained bottom; Pieces 2C (30 cm) to 2D (40 cm), fine-grained top, coarse-grained bottom; Piece 2D (40-45 cm), fine-grained top, coarse-grained bottom; and Piece 4 (75-82 cm), fine-grained top, coarse-grained bottom. Sharpness of contacts not always well defined. Most layers dip at 30°-40°, although this varies. Distribution of olivine defines modal layering. Layering is not always obvious on cut surfaces; the back of pieces show olivine in relief. Piece 2D: Fine-grained section is bounded by medium-grained zones, and is more triangular than layered.

**DEFORMATION:** Slight—some brecciation associated with feldspathic vein at 45-55 and 70 cm, but minor. Several brittle fractures.

**PRIMARY MINERALOGY:**

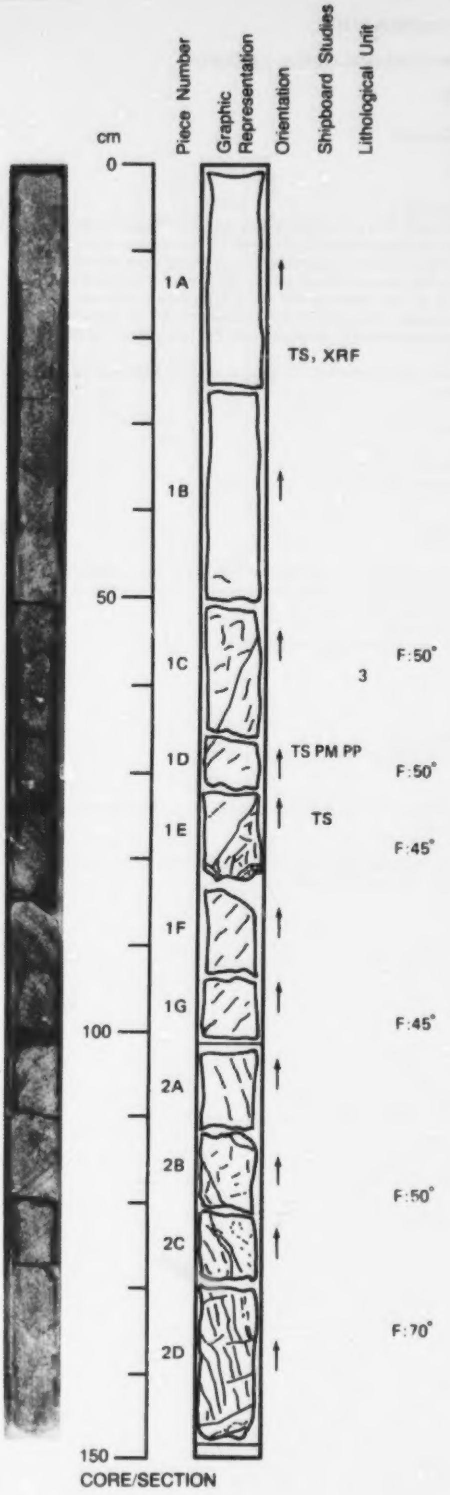
Plagioclase—Mode: 40%-60%.
Crystal size: 0.5-10 mm.
Crystal shape: Euhedral-anhedral.
Preferred orientation: Concentrated in layers.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-60%.
Crystal size: 1-14 mm.
Crystal shape: Subhedral to sub-poikilitic. Can sometimes partially enclose small plagioclase grains. In the coarsest grained sections a pyroxene-dominated layer can sometimes occur along coarse- to fine-grained contact, e.g., Piece 2C.
Preferred orientation: Some lamination.
Percent replacement: 2%-10% amphibolitization. More intense along veins.

Olivine—Mode: 0%-5%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight alteration by undetermined mineral.

**SECONDARY MINERALOGY:**

Total percent: Various.
Texture: Amphibole after pyroxene along veins. Bronze-colored alteration of pyroxene along feldspathic zones at 8 and 70 cm.
Percent vein material: Not determined.
Vein material: Piece 2A (8 cms): Feldspar-amphibole vein cuts foliation. Piece 4 (78 cm): Feldspar-amphibole vein dips at 35° and cuts layering.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1 A
1B
1C
1D
1 E
1F
1G
2A
2B
2C
2D
TS, XRF
TS PM PP
TS
3
F:50°
F:50°
F:45°
F:45°
F:50°
F:70°
CORE/SECTION

**118-735B-41R-4**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-2D**

**Olivine Gabbro**

**Pieces 1A-2D**

**COLOR:** Gray.
**LAYERING:** Grain-size layering seen in Pieces 1C through 1D and 1E (apparent thickness of layers 4 cm), and Pieces 2B through 2D (apparent thickness of layer 3.7 cm). The contact is sharp (<3 mm) and although showing different apparent azimuths, dips "constantly" at 50°. There a foliation that may be magmatic in origin. Grain-size varies from 1-3 mm to 1-6 mm.
**DEFORMATION:** None apparent except for little shearing at the base of Piece 2D.
**PRIMARY MINERALOGY:**

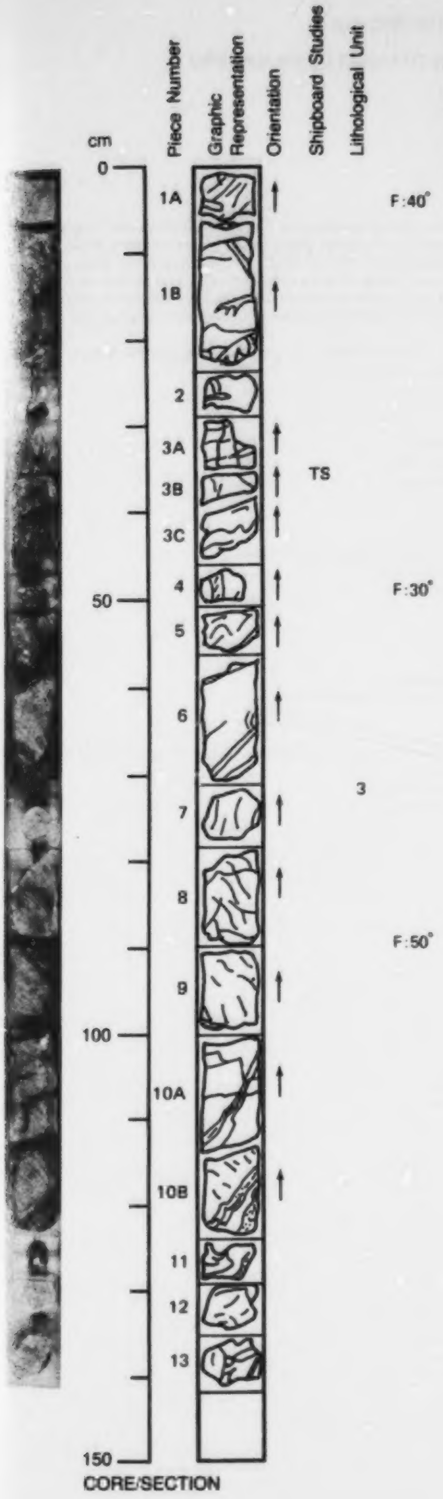
Plagioclase—Mode: Not determined.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight chloritization in Piece 2.

Clinopyroxene—Mode: Not determined.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partial replacement by amphibole.

Olivine—Mode: <1%.
Crystal size: 1-3 mm.
Crystal shape: Rounded.
Preferred orientation: Not apparent.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <4%.
Texture: Coronitic. Pieces 1E and 1F pronounced oxidation (iron oxides). Green amphibole partially replaces clinopyroxene. Plagioclase is chloritized (Piece 2D in particular). Pieces 1A and 1B: Pyrite up to 1%. Pieces 1C and 2A-2C: Pyrite in amounts.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-42R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-13**

**Olivine Gabbro**

**Pieces 1A-13**

**COLOR:** Grayish green to orange, yellowish tinted green.

**LAYERING:** Piece 8: Grain-size layering. Thickness of layer is 2 cm; grains vary from 1 to 2-5 mm in size. There is a preferred orientation paralell to the contact, which is sharp.

**DEFORMATION:** Pieces 1A, 5, 8, and 9: Foliated to poorly foliated. Piece 8: Foliation is parallel to grain-size layering, so secondary and primary foliation may coincide. There is a recrystallization of plagioclase from 2-4 mm to <1 mm neoblasts or granoblasts.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: Slight chloritization and replacement by prehnite.

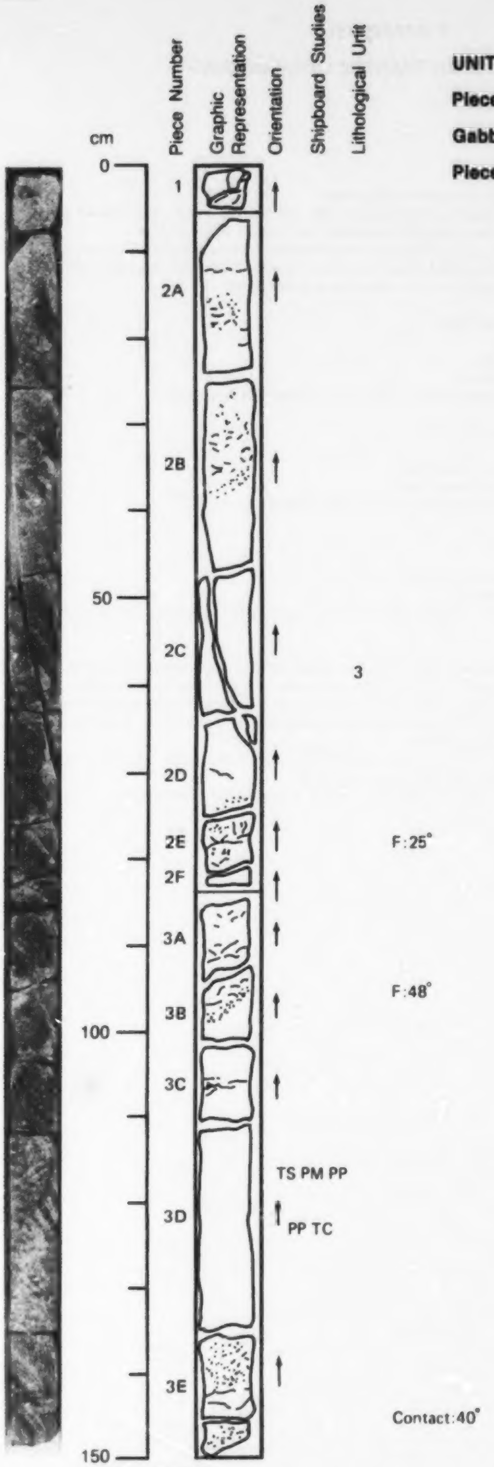
Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral, interstitial.
Preferred orientation: Not determined.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: 1%-4%.
Crystal size: <1 mm.
Crystal shape: Anhedral to rounded.
Preferred orientation: None.
Percent replacement: Completely replaced by iron hydroxide, magnetite, and smectite(?).

**SECONDARY MINERALOGY:**

Total percent: <20%.
Texture: Coronitic pseudomorphic. Olivine is mainly altered to iron hydroxide (brown to orange spots) and magnetite (and smectite ?). Clinopyroxene is replaced by amphibole (two types: pseudomorphs and rims) and stained by orange clays. Plagioclase is chloritized and replaced by fibrous prehnite in cavities; yellowish iron hydroxides are also present. Wall rocks are preferentially altered to amphibole.
Percent vein material: Not determined. Veining abundant in Pieces 1B, 2-5, 7, and 10B-13.
Vein material: Amphibole (20%), plagioclase (80%).

**COMMENTS:** This section comprises a foliated to poorly foliated olivine-poor gabbro.



## 118-735B-42R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1-3E

### Gabbro and Olivine Gabbro

### Pieces 1-3E

**COLOR:** Gray.

**LAYERING:** Many complex coarse- to fine-grained transistions. Pieces 2D-3B (70-95 cm): Coarse- to fine-grained sequence; at the bottom is a very sharp change to a fine-grained zone. Piece 3D: Uniformly medium-grained. Pieces 2A (16 cm) and 2B (33 and 36 cm): Contain small coarse-grained "lenses" in a fine-grained "matrix." Pieces 2A (20-25 cm), 2D (63-65 cm), 3A (86 cm), 3C (103-108 cm), and 3D (128-132 cm): Contain olivine-rich zones but are difficult to define. Where clear, there is no consistent relationship to the coarse- to fine-grained variation. The dip of the transitions is not constant.

**DEFORMATION:** Some shearing. Piece 1: Porphyroclastic textures. Pieces 2C and 2D: Steeply dipping to vertical fractures with offsets of up to 10 cm.

**PRIMARY MINERALOGY:**

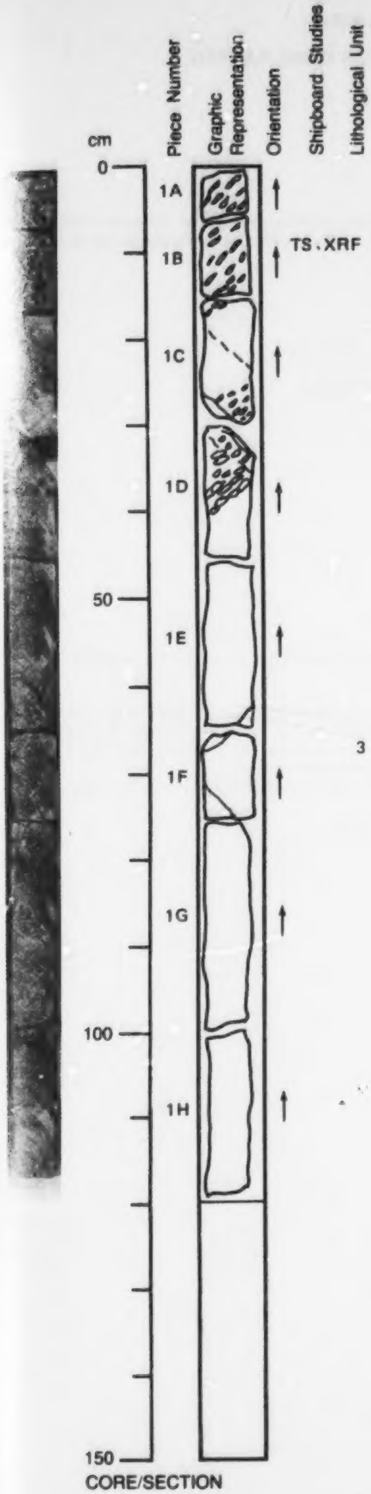
Plagioclase—Mode: 60%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Slight lamination.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%.
Crystal size: 1-8 mm, large oikocrysts.
Crystal shape: Anhedral (ophitic to subophitic) to subhedral.
Preferred orientation: Slight lamination.
Percent replacement: 5% by amphibole.

Olivine—Mode: 0%-8%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 10%-20% by talc and amphibole.

**SECONDARY MINERALOGY:**

Total percent: Slight.
Texture: Pieces 1 and 3C: Amphibole along some fractures. Pieces 2C and 2D: Thin feldspathic veins fill steeply dipping fractures.
Percent vein material: Not determined.
Vein material: Amphibole and feldspar.



## 118-735B-42R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-1H

### Olivine Gabbro

### Pieces 1A-1D (43 cm)

**COLOR:** Gray.
**LAYERING:** Size- and phase-graded layering downsection from medium- to coarse-grained olivine gabbro to olivine-bearing microgabbro, and then back to coarse-grained olivine-bearing gabbro.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 0.5-10 mm or locally larger.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 33%.
Crystal size: 0.5-5 mm or locally larger.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10% by amphibole.

Enstatite—Mode: 5.5%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10% by amphibole.

Olivine—Mode: 4%, but varies from 1% to 7%.
Crystal size: 0.2-3.0 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 25% locally by talc, amphibole, and magnetite.

Brown Hornblende—Mode: <1%.
Crystal size: <0.1 mm.
Crystal shape: Interstitial rim on opaques.
Preferred orientation: None.
Percent replacement: None

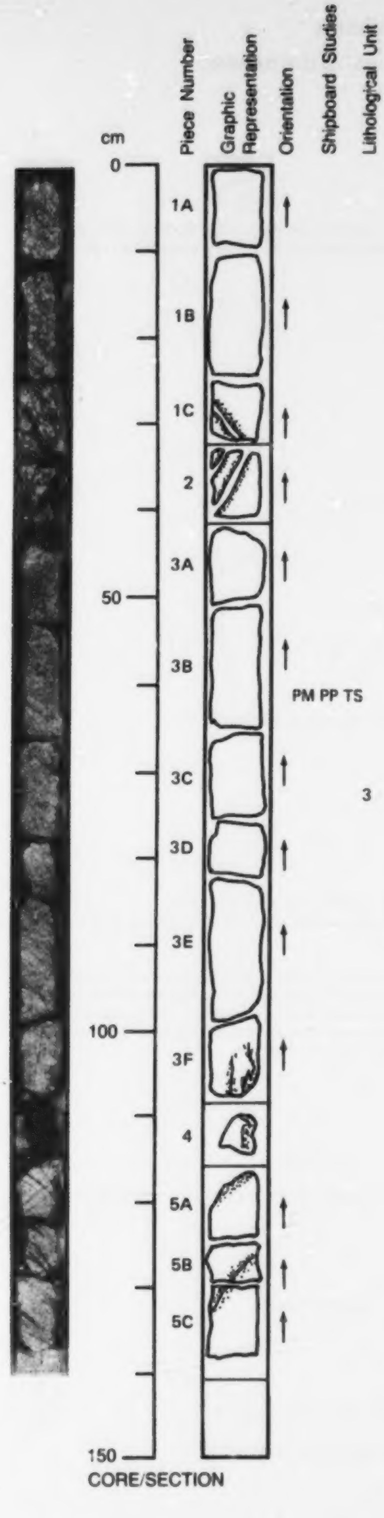
Opaques—Mode: 1%.
**SECONDARY MINERALOGY:**
Total percent: 3.5%, (talc 0.3%, amphibole 3.0%, and magnetite 0.2%).
Texture: Talc, amphibole, and magnetite locally replacing olivine. Amphibole locally replaces and rims clinopyroxene.
Percent vein material: Not determined.
Vein material: Plagioclase, amphibole, talc or smectite, and carbonate (0.3%). Pieces 1C and 1D: 4 mm thick plagioclase vein inclined at 45° contains a band of yellow talcose material at its center 1 mm thick. The gabbro on each side of the vein is altered to an amphibole-rich, greenish-gray rock, in a 2-cm-wide zone on the lower side and contains a single 4-cm-wide zone on the upper side of the vein. Piece 1A: Carbonate vein.

### Gabbro

### Pieces 1D (43 cm)-1H

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Weak foliation defined by shape parallel to the layering in the olivine gabbro. May be an igneous limation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Slight elongation parallel to layering.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 1-15 mm or larger.
Crystal shape: Anhedral, granular.
Preferred orientation: Slight elongation parallel to layering.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:** Similar to olivine gabbro described above.



## 118-735B-42R-4

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-5C**

**Olivine Gabbro**

**Pieces 1A-5C**

**COLOR:** Gray.

**LAYERING:** Possible primary layering shown by slight preferred orientation of pyroxenes in Pieces 1B and 1C, and alternating medium- to coarse-grained textures, as in Pieces 3A and 5C. This layering dips at approximately 50°.

**DEFORMATION:** No apparent foliation.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 45%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 1% by undetermined mineral.

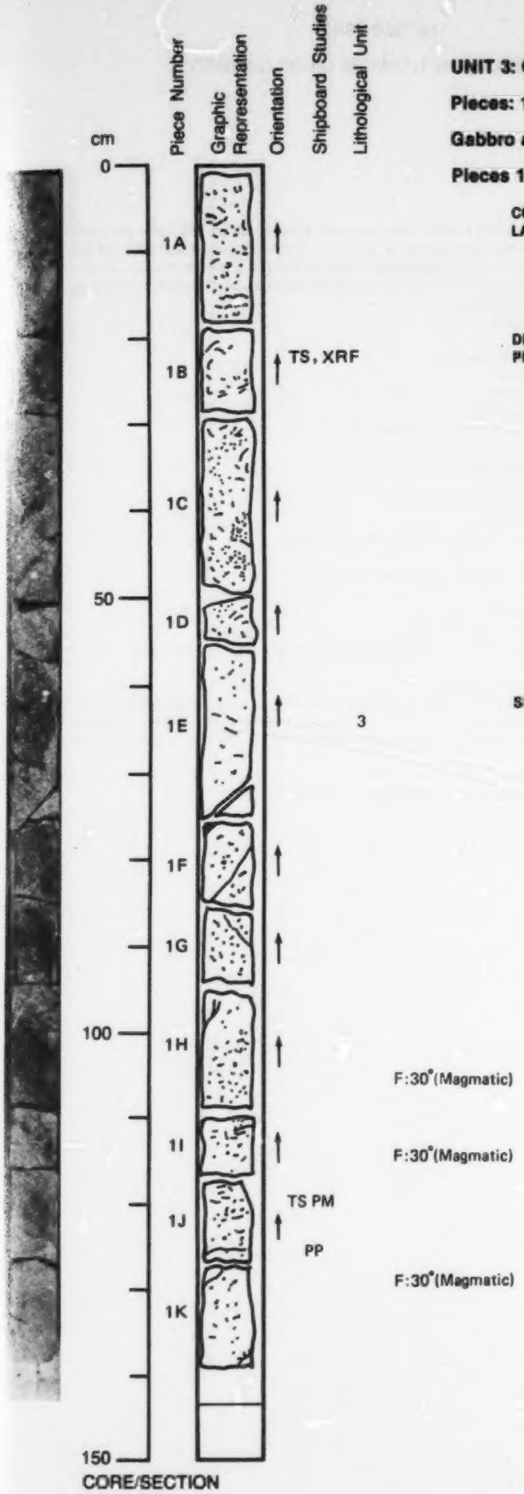
Clinopyroxene—Mode: 45%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 1% by amphibole.

Olivine—Mode: 10%.
Crystal size: 1-7 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 1%.

**SECONDARY MINERALOGY:**

Total percent: generally <5%-10%.
Texture: This section is relatively fresh, except adjacent to veins. Typically, amphibole replaces clinopyroxene. Traces of sulfides throughout.
Percent vein material: 5%.
Vein material: Fibrous actinolite and chlorite. Pieces 2, 5B, and 5C: Veins filled and fractures lined by soft, greenish-white mineral, probably chlorite. Pieces 3F, 4, and 5A: Portions of a vein contain fibrous actinolite, a white mineral, probably talc, and possible chlorite. Actinolite is fibrous and grows radially in veins as if into an open fracture.

**COMMENTS:** Clinopyroxene does not indicate the common textures shown in previous cores.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
1F
1G
1H
1I
1J
1K
TS, XRF
TS PM
PP
3
F:30°(Magmatic)
F:30°(Magmatic)
F:30°(Magmatic)
CORE/SECTION

## 118-735B-43R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces: 1A-1K

### Gabbro and Olivine Gabbro

### Pieces 1A-1K

**COLOR:** Gray.

**LAYERING:** Many coarse- to fine-grained variations appear in the section, which appears to be more lensoid than layered in distribution. Patches and pods of medium- to coarse-grained material in a microgabbro matrix are common. Pieces 1A and 1K are good examples. Olivine irregularly distributed and may represent crude layering. Olivine-rich layers occur at 0-25, 40, 45, 70-73, 85-87, 105-107, and 124-125 cm. Pieces 1H-1J: A feeble foliation is defined by clinopyroxene elongation.

**DEFORMATION:** A few fractures.

**PRIMARY MINERALOGY:**

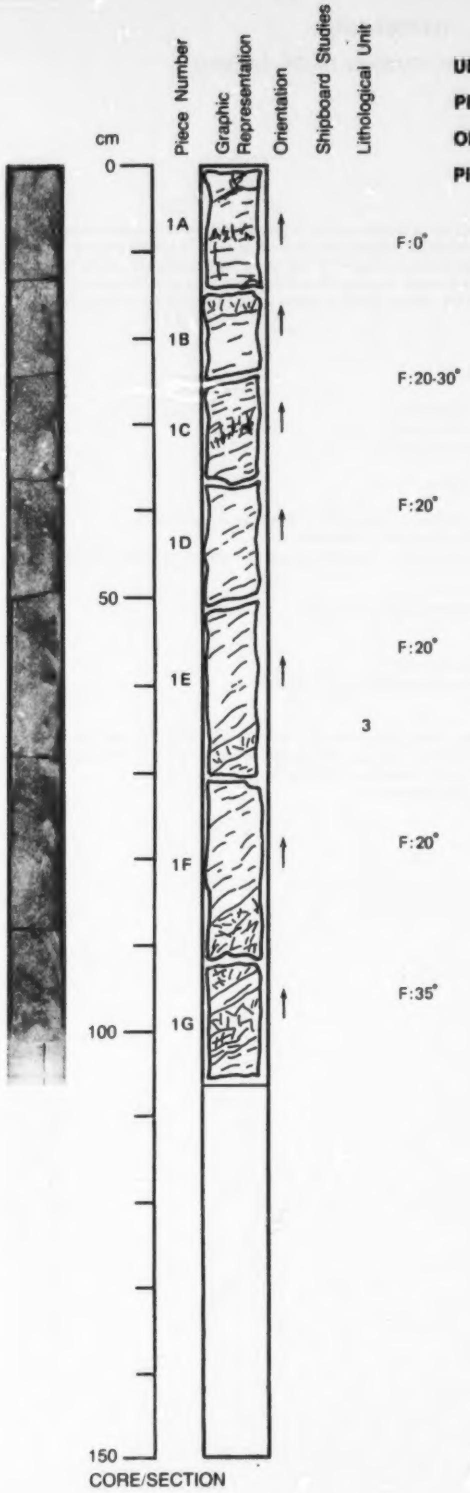
Plagioclase—Mode: 50%-60%.
Crystal size: 5-7 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%-55%.
Crystal size: 0.5-10 mm.
Crystal shape: Subhedral to anhedral, interstitial to granular, no oikocrysts.
Preferred orientation: Slight lamination in some pieces.
Percent replacement: Minor amphibole replacement except along veins where replacement is intense.

Olivine—Mode: 15% in parts of Pieces 1A and 1B.
Crystal size: 0.5-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Minor replacement by talc and tremolite.

**SECONDARY MINERALOGY:**

Total percent: Minor.
Texture: Amphibole replaces clinopyroxene along a few fractures at 80, 125, and 138 cm. Pyrite occurs as <0.5 mm grains at 25 cm and in parts of the top half of the core. The rock is very fresh; pyrite not associated with the veins, may be primary.
Percent vein material: Not determined.
Vein material: Amphibole.



**118-735B-43R-2**

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1G**

**Olivine Gabbro**

**Pieces 1A-1G**

**COLOR:** Gray.

**LAYERING:** Pieces 1A-1C and 1E-1F: Grain-size variations evident. Layers are 1 to 4 cm thick with a thicker medium- to fine-grained interval at 55 cm. Thick, coarse-grained intervals contain less olivine (2%-3%). Foliation is subparallel to the contacts of probable primary origin. Difference between the contact and foliation dips can be as much as 20°. The pyroxene and plagioclase are preferrentially oriented.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

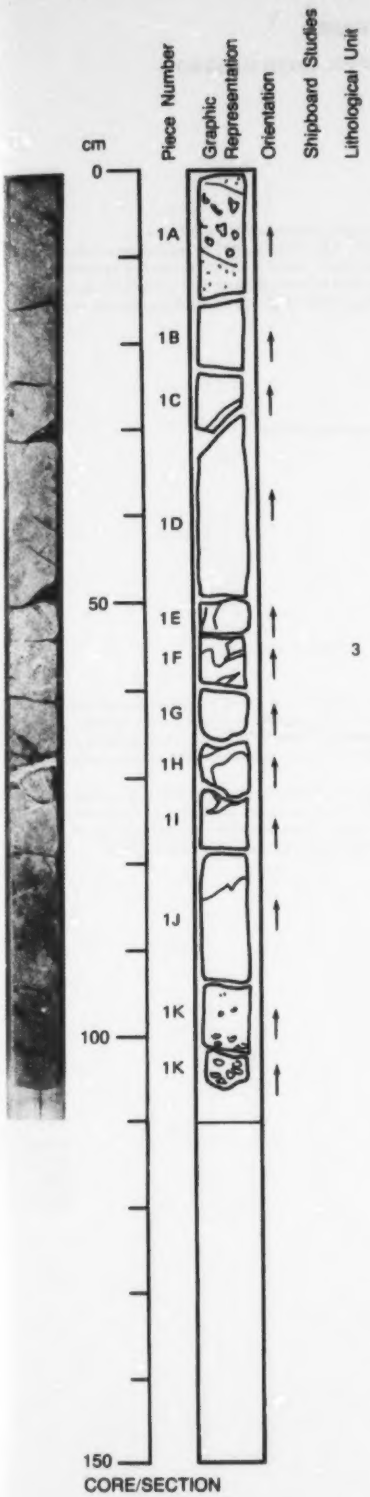
Plagioclase—Mode: 50%-60%.
Crystal size: 0.5-4 mm.
Crystal shape: Prismatic.
Preferred orientation: Yes.
Percent replacement: Partially chloritized.

Clinopyroxene—Mode: 40%-48%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Yes.
Percent replacement: Partially replaced by amphibole.

Olivine—Mode: 2%-10% (20% in Pieces 1C and 1D).
Crystal size: 1-3 mm.
Crystal shape: Rounded.
Preferred orientation: Not determined.
Percent replacement: Slight to moderate replacement by iddingsite and talc.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Coronitic. Clinopyroxene is partially replaced by amphibole. Clays and iron hydroxides stain the core of the grains. Olivine is partly altered to iddingsite and talc. Plagioclase is partially chloritized (greenish color). Disseminated pyrite (<0.5 mm) is present in all pieces (up to 1% in Piece 1E).
Percent vein material: Pieces 1A-1G: <1%.
Vein material: Amphibole and plagioclase, <1 mm thick.



## 118-735B-43R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-1K

### Olivine Gabbro and Gabbro

### Pieces 1A-1K

**COLOR:** Gray.

**LAYERING:** Both phase and size layering present: 0-10 cm—olivine gabbro with 3% olivine, coarse-grained, underlies a small horizon of medium-grained gabbro. 10-76 cm—gabbro containing <1% olivine, medium- to coarse-grained, equigranular with local modal variations defining faint pyroxene-rich layers. 80-92 cm—coarse-grained gabbro (no visible olivine) with 2 cm average grain size and local 2-cm-thick vein of microgabbro. 92-108 cm—olivine gabbro with 5% olivine, size graded downward from medium- to coarse-grained (1 mm to 1 cm).

**DEFORMATION:** No penetrative deformation noted, although brittle deformation evident from crosscutting, high-temperature, plagioclase- and amphibole-filled veins.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%-70%.
Crystal size: Not determined.
Crystal shape: Equigranular anhedral.
Preferred orientation: None noted.
Percent replacement: Little evident.

Clinopyroxene—Mode: 30%-35%.
Crystal size: Locally greater in 1 cm thick layers.
Crystal shape: Anhedral granular to subhedral (0-10 cm).
Preferred orientation: Piece 1A: Weak igneous lamination defined by pyroxene lying subhorizontal to layer boundaries.
Percent replacement: 0%-100%, highly variable, depending on interval. Pyroxene is rimmed or pseudomorphed by amphibole.

Olivine—Mode: 0%-5%.
Crystal size: Not determined.
Crystal shape: Granular.
Preferred orientation: None noted.
Percent replacement: Variable, some totally pseudomorphed in gabbro near crosscutting veins.

Sulfides—Mode: Trace-0.5%, most abundant in lower olivine gabbro, where as many as three different disseminated sulphides are seen together—possibly pyrite, chalcopyrite, and arsenopyrite (?). Small pyrite grains scattered in the coarse-grained gabbro stain the silicate matrix orange-red in their proximity.

**SECONDARY MINERALOGY:**

Total percent: Highly variable—quite fresh away from veins, extensive near them with amphibole replacing pyroxene.
Texture: Clinopyroxene replaced by amphibole. Pieces 1E-1I (48-74 cm): Alteration is extensive centered on thick (1 cm) veins of feldspar and amphibole crosscutting the gabbro.
Percent vein material: Highly variable, 20% in some pieces, absent in the upper one-third of the section.
Vein material: Pieces 1E-1I: Plagioclase-rich veins up to 1 cm wide crosscut the core and appear to contain some amphibole. Piece 1K: Green smectite (?) or other clay mineral present on fracture surfaces between halves.

### 118-735B-43R-4

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1-8B**

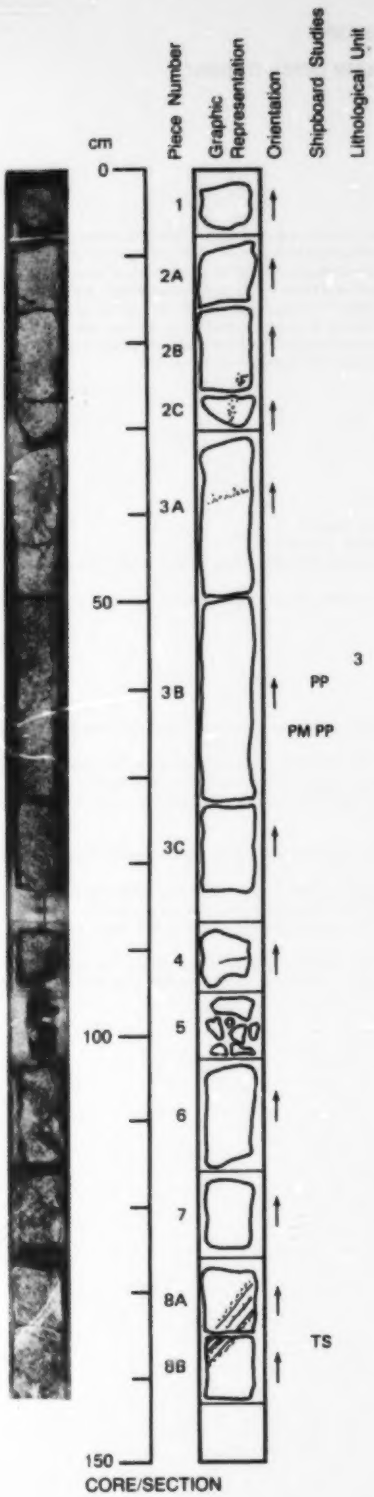
**Olivine Gabbro**

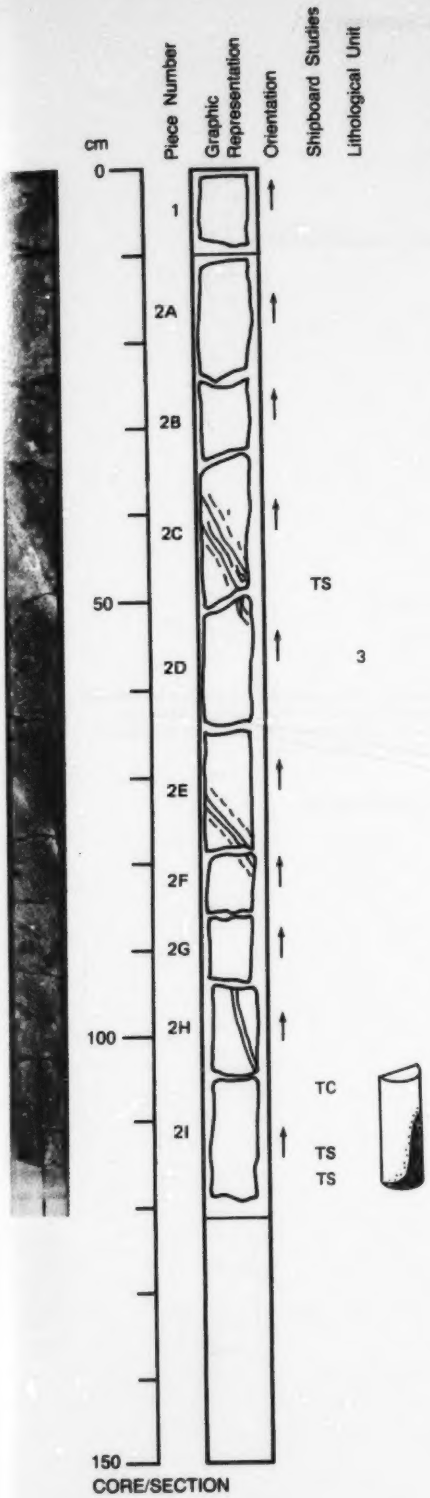
**Pieces 1-8B**

**COLOR:** Gray.
**LAYERING:** Possible primary layering defined by grain size variation, as in Piece 6.
**DEFORMATION:** Suggestion of foliation in Pieces 3A-3G. Other pieces in section have a crude horizontality, possibly layering. In Pieces 3A-3G, there is a gradual rotation away from this horizontal to a very steep "foliation" defined by elongation of, and preferred orientation of, pyroxene (approximately 55° from the horizontal). This may be a primary texture of the magma chamber rather than deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%-20% by undetermined mineral.

Clinopyroxene—Mode: 50%-45%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 40% by amphibole.

Olivine—Mode: 0%-5%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 80%-100% by orangish-brown iron oxides.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Alteration variable. Pieces 1, 4-7, and part of 8 are very fresh, alteration less than 5%-10%. Olivine relatively unaltered. In Pieces 2A-C and 3A-C, section is more altered. Clinopyroxene partially replaced by amphibole, olivine is altered to orangish-brown iron oxides. Pieces 2 and 3: Scattered concentrations of ilmenite. Traces of sulfides throughout.
Percent vein material: Not determined.
Vein material: Sodic plagioclase, actinolite, and chlorite. Piece 3A: Veins of a white mineral, probably sodic plagioclase. Pieces 8A-8B: Veins are zoned, consisting of white mineral ± chlorite at edges and green minerals in center, probably actinolite. Although vein is approximately 1 cm wide, there seems to be little alteration halo adjacent to it.





### 118-735B-44R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1-2I

### Olivine Gabbro and Coarse- to Medium-Grained Gabbro

### Pieces 1-2I

**COLOR:** Gray.

**LAYERING:** Weak primary igneous lamination inclined at about 45° in the medium- and moderately coarse-grained sections, reflects slight preferred orientation of pyroxene and plagioclase. Grain size varies from medium- to coarse-grained, while the texture is equigranular anhedral to subhedral. There is a coarser interval between 25 and 50 cm.

**DEFORMATION:** Not determined.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-20 mm.
Crystal shape: Equigranular anhedral to subhedral.
Preferred orientation: Slight shape orientation locally.
Percent replacement: Locally 0%-100%, highly variable, intense near some veins; plagioclase replaced by albite, epidote, and chlorite.

Clinopyroxene—Mode: 50%-40%.
Crystal size: 1-20 mm.
Crystal shape: Equigranular anhedral to subhedral.
Preferred orientation: Slight shape orientation locally.
Percent replacement: 0%-100%, highly variable, intense near veins; clinopyroxene replaced by amphibole.

Olivine—Mode: 0%-20%, highly variable, appears absent in large portions. Abundant in the bottom 3 cm of gabbro above the iron-titanium oxide gabbro.
Crystal size: 0.5-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60%-100%, locally pseudomorphed by talc, magnetic, and tremolite.

**SECONDARY MINERALOGY:**

Total percent: Variable.
Texture: Alteration is generally weak in the upper half of the section with a small vein (1 mm) of amphibole in Piece 1A. In the lower half of the section, a 1.5-cm-thick vein of plagioclase is present. Pale green amphibole rims and replaces primary pyroxene and plagioclase in the gabbro for about 1 cm to either side of the vein. Piece 2C: Several 0.3-mm-thick veins of green amphibole cut the gabbro. Piece 2E: Plagioclase and darker amphibole vein (2 mm) crosscuts through core; the gabbro is subject to amphibole alteration for 1 cm to each side of the vein. Pieces 2F, 2G, and 2H: Cut by a 3-mm-thick vein of green amphibole. These pieces are far more extensively amphibolitized than the remaining gabbro.
Percent vein material: 3%.
Vein material: Amphibole and plagioclase.

**118-735B-44R-1 (continued)**

## Olivine Gabbro—Massive Iron-Oxide Gabbro

### Piece 2I

**COLOR:** Not determined.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 20%.
Crystal size: 1-10 mm.
Crystal shape: Euhedral to anhedral, interstitial to massive ilminite.
Preferred orientation: None.
Percent replacement: Small.

Clinopyroxene—Mode: 20%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Small.

Olivine—Mode: 2%-5%.
Crystal size: 0.5-3 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Relatively fresh.

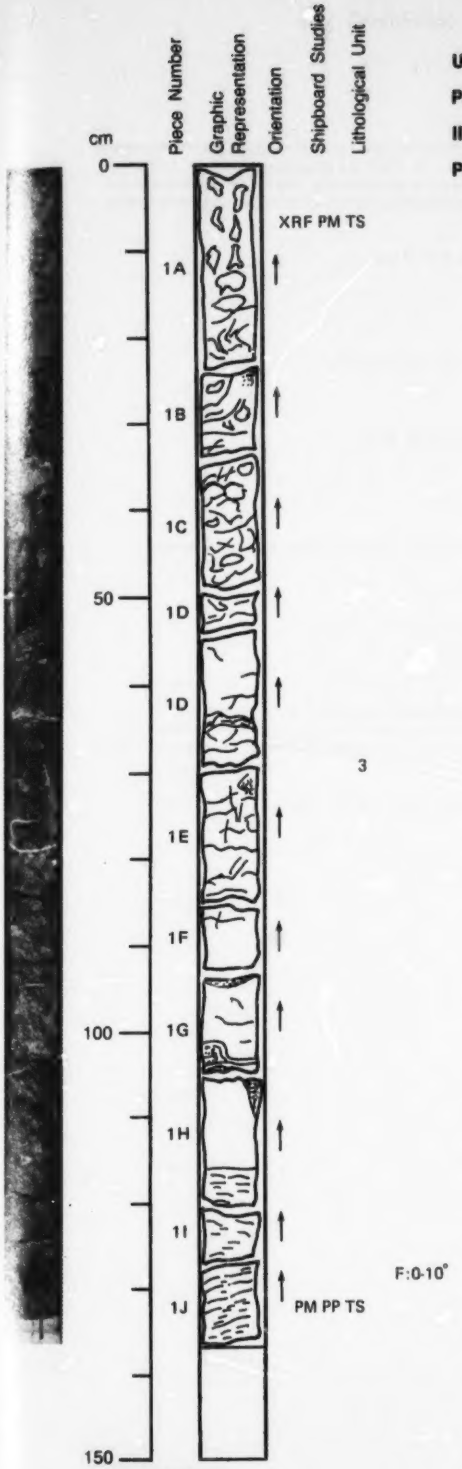
Ilmenite—Mode: 50%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Up to 60% by a green mineral.

Iron-copper sulphides—Mode: 8%, disseminated.

**SECONDARY MINERALOGY:**

Total percent: 15%-40%.
Texture: Plagioclase is interstitial to ilmenite, while clinopyroxene and plagioclase poikilitically enclose blebs of ilmenite and sulfide. Fresh olivine also occurs in the section. Alteration includes formation of malachite in cracks in the sulfides. Some amphibole may be present in the pyroxene. Ilmenite locally altered (up to 60%) to a green mineral.
Percent vein material: None.
Vein material: None.

**COMMENTS:** Located on an inclined (70°) zone on the back of Piece 2I.



## 118-735B-44R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1J**

**Ilmenite-Rich Gabbro**

**Pieces 1A-1D**

**COLOR:** Gray to grayish black.

**LAYERING:** Not apparent, although there are subvertically oriented pyroxene grains in Pieces 1B, 1C, and 1D. This is a primary mineral lineation inclined from subvertical to 70°.

**DEFORMATION:** Not apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Strong (primary).
Percent replacement: Slight chloritization.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 3-17 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: Trace amounts.
Crystal size: 1-2 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: Slight.

Ilmenite—Mode: 15%-30%.
Crystal size: 1-10 mm (veining).
Crystal shape: Ilmenite is granular.
Preferred orientation: Occurs as inclusions in clinopyroxene or fills interstitial spaces between silicates; this veining is subvertical, indicating a primary origin for ilmenite.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: $<10\%$.
Texture: Coronitic. Clinopyroxene is slightly replaced by amphibole and plagioclase is slightly chloritized. Different sulfides are present as disseminated phases in close association with ilmenite. These are chalcopyrite and pyrite. Chalcopyrite is altered to malachite. Sulfides are secondary, as they are often found in cracks.
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole. Piece 1D (bottom): Plagioclase-rim vein, 1 cm across, plagioclase is mixed with chlorite and amphibole(?).

## 118-735B-44R-2 (continued)

### Olivine Gabbro

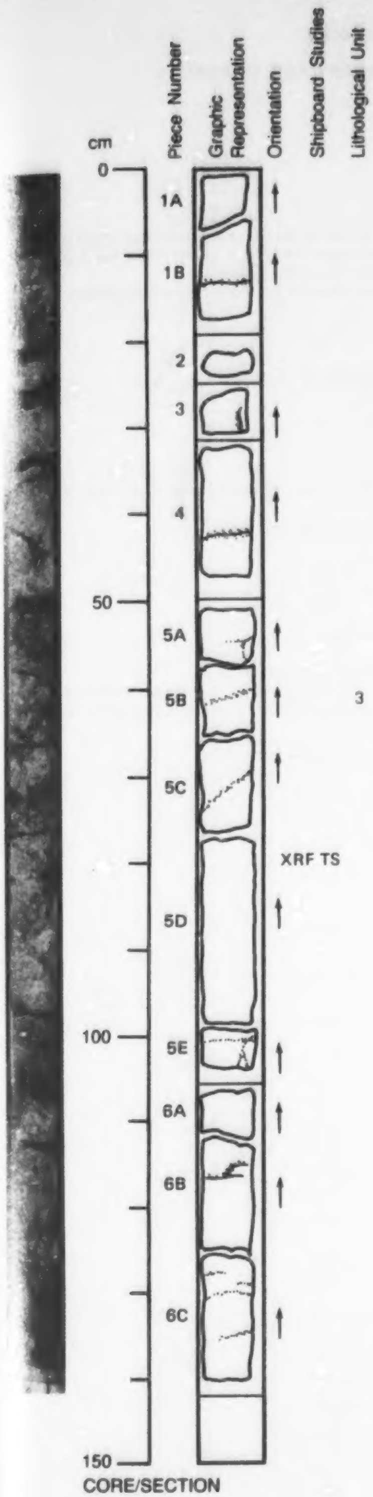
### Pieces 1E-1J

**COLOR:** Gray to greenish gray.
**LAYERING:** Piece 1H: Grain-size layering evident. The fine-grained interval is olivine-gabbro, the coarse-grained interval is olivine-poor gabbro. Piece 1E: There is a progressive decrease in ilmenite from 4% to 1% and a complementry increase in modal olivine. This section is texturally and mineralogically zoned. The medium-grained olivine gabbro is foliated, see other descriptions.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60% (Piece 1E), 50%-55% (Piece 1J).
Crystal size: 1-4 mm.
Crystal shape: Rounded to anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 30%-40% (Piece 1E), 45% (Piece 1J).
Crystal size: 1-3 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: 2%-5% (Piece 1J).
Crystal size: 1-2 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: Slight replacement by iddingsite, hydroxides, and clay minerals.

Ilmenite—Mode: 1%-4% (Piece 1E).
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: < 10%.
Texture: Coronitic. Olivine is replaced by iddingsite, hydroxides, and clay minerals. Clinopyroxene is partly replaced by amphibole. Chalcopyrite and pyrite are disseminated in the gabbro. Chalcopyrite is altered to malachite. The amount of sulfides decreases as ilmenite content decreases.
Percent vein material: < 1%.
Vein material: Pieces 1G and 1H: Veins filled by plagioclase. Pieces 1E and 1F: Cracks, < 1 mm thick, are filled by plagioclase.
**COMMENTS:** Coarse- to medium-grained gabbro.



## 118-735B-44R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-6C**

**Olivine Gabbro—Ilmenite and Sulfide-Bearing**

**Pieces 1A-6C**

**COLOR:** Dark gray.

**LAYERING:** Pieces 1A and 1B: Possible primary layering defined by alternating medium to coarse grain size. Pieces 5A and 5G: Some mineralogical variation, olivine is concentrated in diffused layers.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: None.
Percent replacement: <1% by albite.

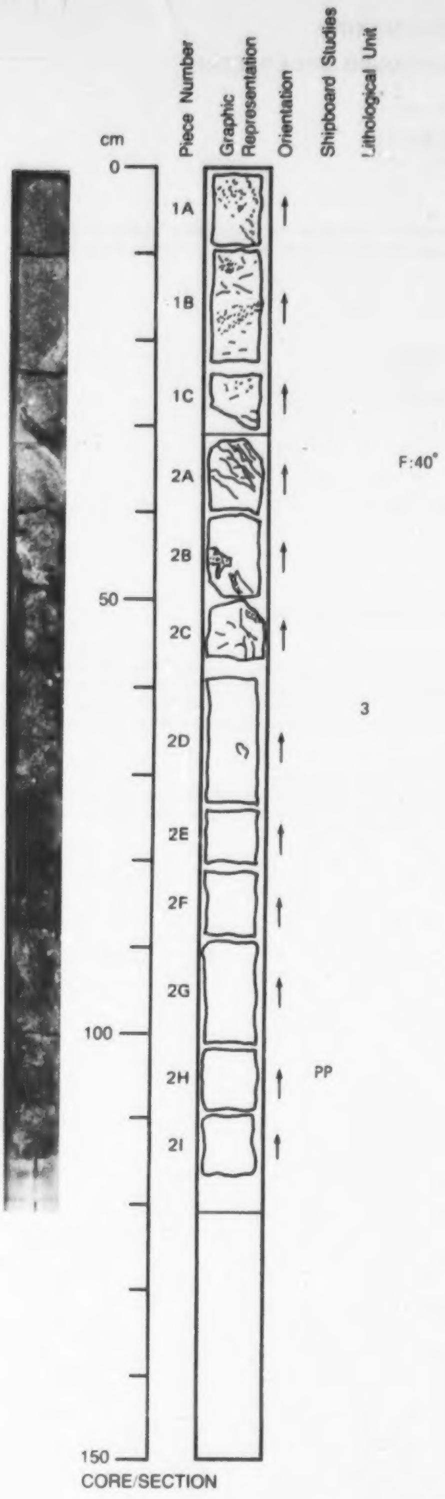
Clinopyroxene—Mode: 40%.
Crystal size: 1-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Olivine—Mode: 10%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%-100% by orangish minerals.

**SECONDARY MINERALOGY:**

Total percent: Slight.
Texture: Alteration variable. Most plagioclase is unaltered. Alteration tends to be associated with proximity to thin veins, rather than to selective replacement of phases. Pieces 3-6C: 15%-20% replacement by green amphibole. Pieces 2 and 5C: Some albitization adjacent to veins. Olivine is generally fresh, but can vary from fresh to totally replaced by orangish minerals over a distance of 0-3 cm.
Percent vein material: 3%-4%.
Vein material: green amphibole and sodic plagioclase.

**COMMENTS:** Plagioclase subophitically enclosed in clinopyroxene in Pieces 5A-E. Concentrations of silver-colored, iron oxides, either ilmenite (or titanium magnetite) and sulfides may be primary.



## 118-735B-44R-4

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces: 1A-2I**

### Olivine Gabbro

**Pieces 1A-2I**

**COLOR:** Gray; Gray-white in alteration zones.

**LAYERING:** No clearly defined layering. Pieces 1A and 1B contain fine-grained pods. Piece 2C: Coarse grained (up to 2 cm). Pieces 2D-2I: Uniform grain size (1 cm). Olivine throughout section, but particularly abundant at 20-22 cm (2-5 mm grain size).

**DEFORMATION:** Shear zone at 34 cm. Feldspathic vein at 47 cm. Piece 2B: Most of piece is altered or broken up.

**PRIMARY MINERALOGY:**

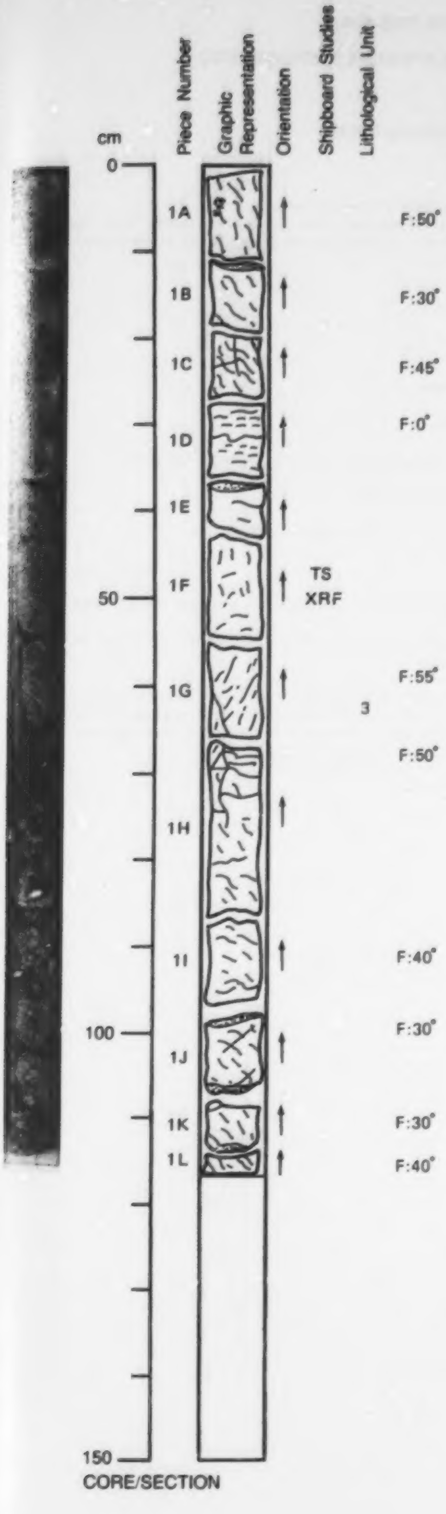
Plagioclase—Mode: 40%-60%.
Crystal size: 5-8 mm.
Crystal shape: Anhedral, euhedral, small euhedral grains in clinopyroxene.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 50%-40%.
Crystal size: 0.5-2.5 mm.
Crystal shape: Subhedral to poikilitic; rare large oikocrysts in Pieces 1B, 2C, and 2H.
Preferred orientation: None.
Percent replacement: Significant amphibolitization near veins.

Olivine—Mode: 25-8%.
Crystal size: 1-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Webbed by talc-tremolite.

**SECONDARY MINERALOGY:**

Total percent: Various, concentrated in shear zones and veins.
Texture: Green amphibole after pyroxene in shear zone at 33 cm and near the feldspathic vein at 48 cm. Some ilmenite along feldspathic vein. Piece 2H: Pyrite. Pieces 2A-2I: Anhedral oxide throughout.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-45R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1L**

**Olivine Gabbro**

**Pieces 1A-1L**

**COLOR:** Gray to greenish gray.
**LAYERING:** None apparent. There is a grain-size change between Pieces 1G (1-5 mm) and 1H (1-10 mm). The contact is not seen. The observed foliation is primary and enhanced by preferred orientation of plagioclase and clinopyroxene.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:** There is a modal variation throughout the core.

Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm, 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Slight.
Percent replacement: Slight replacement by chlorite.

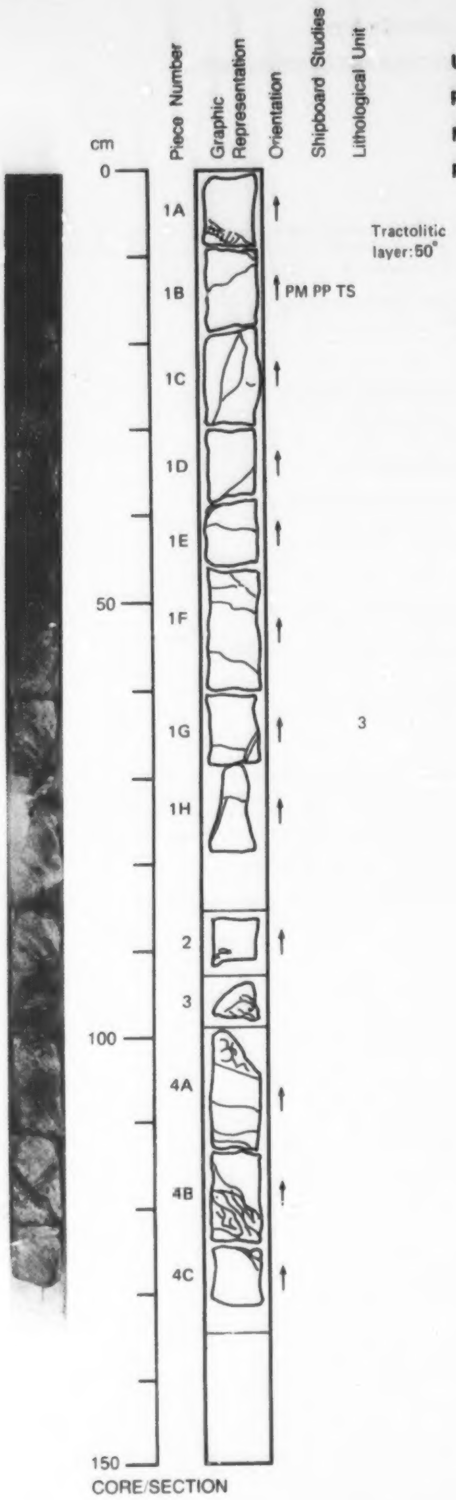
Clinopyroxene—Mode: 35%-40%, 35%-50%.
Crystal size: 1-3 mm, 3-5 mm.
Crystal shape: Oikocrystic irregular, anhedral.
Preferred orientation: Slight.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: 2%-5% (present in Pieces 1H-1L).
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Slight.
Percent replacement: Slight replacement by talc and tremolite.

Ilmenite—Mode: 1%-4% (abundant in Pieces 1A, 1C, and 1D).
Crystal size: 1-8 mm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: <1%.
Texture: Coronitic. Oikocrystic-type clinopyroxene starts at Piece 1H and is coronitic to the bottom of the section. There is slight replacement of clinopyroxene by amphibole, olivine by talc and tremolite, and plagioclase by chlorite. Veins are filled by plagioclase and have amphibole-rich walls. Pyrite and chalcopyrite are present in all pieces. A blue sulfide may derive from the alteration of chalcopyrite (bornite or coveilite?).
Percent vein material: Not determined, but inferred as <1%.
Vein material: Plagioclase and amphibole.

**COMMENTS:** Massive to foliated (primary) gabbros and olivine gabbros. Very fresh.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
1F
1G
1H
2
3
4A
4B
4C
PM PP TS
Tractolitic layer: 50°
3
CORE/SECTION

## 118-735B-45R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-4C**

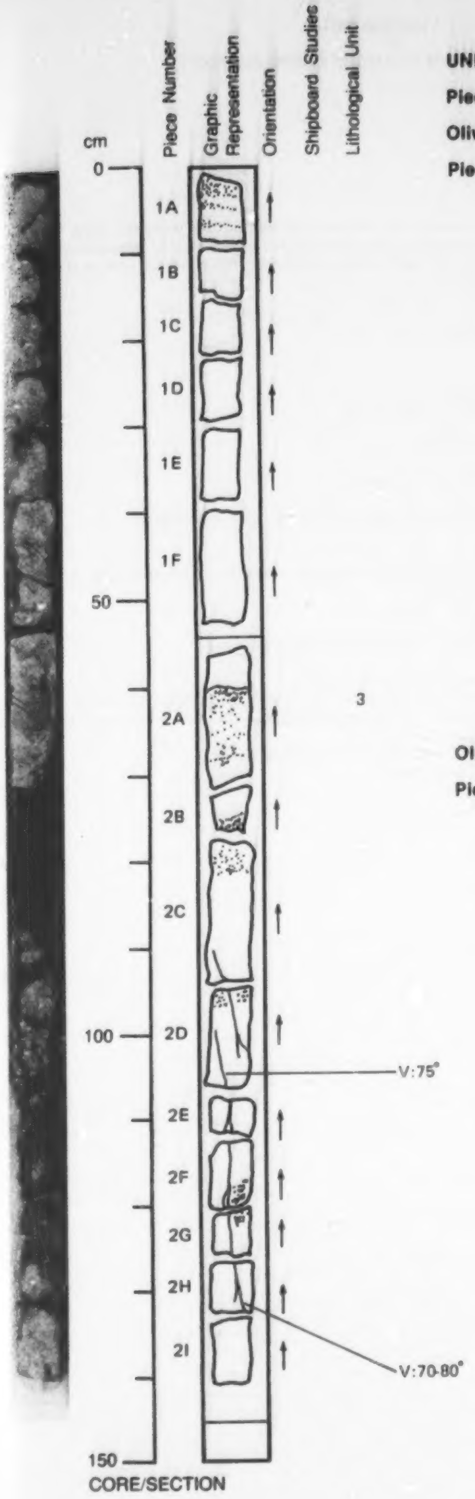
**Massive Olivine Gabbro and Olivine-Bearing Gabbro**

**Pieces 1A-4C**

**COLOR:** Medium gray, to greenish-brown gray in some intervals.
**LAYERING:** There may be some faint primary layering in the top half of the section. Grain size varies from coarse-grained (Pieces 1A-1F) to medium-grained (Pieces 1G-4B) to fine-grained (Piece 4C).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Variable, 1-4 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 5% by albite.

Clinopyroxene—Mode: 45%-30%.
Crystal size: Variable 0.5-3 mm.
Crystal shape: Anhedral, oikocrysts of clinopyroxene in coarse-grained gabbro.
Preferred orientation: None.
Percent replacement: 5%-15% by amphibole.

Olivine—Mode: 5%-20%. Piece 1A: Troctolitic layer, 1 cm thick.
Crystal size: Variable, 0.5-1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <1%; Olivine mostly fresh, especially in the top half of the section.
**SECONDARY MINERALOGY:**
Total percent: 5% in the top half of the section, 15% in the lower half of the section.
Texture: Amphibole replacement.
Percent vein material: 5%.
Vein material: Amphibole with albitized margins. Pieces 1C and 3: Amphibole veins. Piece 4B: Amphibole vein with analcite(?). Pieces 1A-1C: Amphibole content increases from to 10%-15%. Veins with green amphibole, especially in lower parts of the section. Some albitization along margins. Pieces 1A-1C: Contain small, disseminated sulfides.



## 118-735B-45R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-2I

### Olivine Microgabbro

### Pieces 1A and 2A-2C (top)

**COLOR:** Pale greenish gray.
**LAYERING:** Massive. The microgabbro forms layers within the coarser-grained gabbro. Weak igneous lamination is defined by bands of coarser-grained olivine and clinopyroxene.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 70%.
Crystal size: <1 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 15%-20%.
Crystal size: <1 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to amphibole.

Olivine—Mode: 10%-15% (locally up to 25%).
Crystal size: <1 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to talc and tremolite.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Clinopyroxene altered to amphibole, olivine altered to talc and tremolite. Alteration halos around veins.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Equigranular.

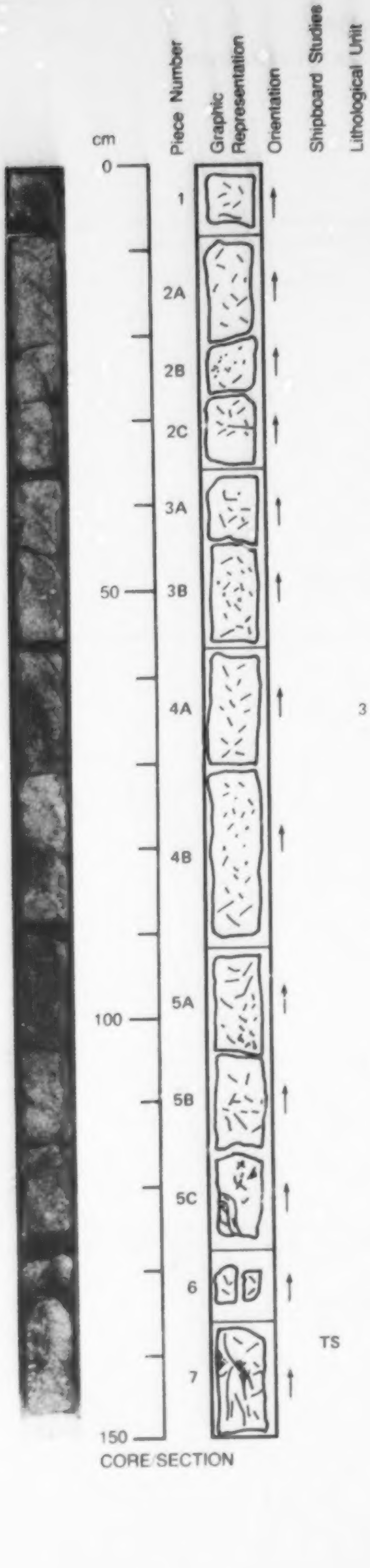
### Olivine Gabbro

### Pieces 1B-1F, and 2C (bottom)-2I

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** Granulation near veins.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-70%.
Crystal size: 3-15 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: Minor recrystallization.

Clinopyroxene—Mode: 25%.
Crystal size: 3-15 mm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Replaced by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 3-12 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Amphibole replaces clinopyroxene. Granulation and minor recrystallization of plagioclase. Veins up to 1 mm wide are filled with amphibole and sodic plagioclase. Alteration halos around veins up to 1 cm wide.
Percent vein material: Not determined.
Vein material: Amphibole and sodic plagioclase.



## 118-735B-45R-4

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1-7**

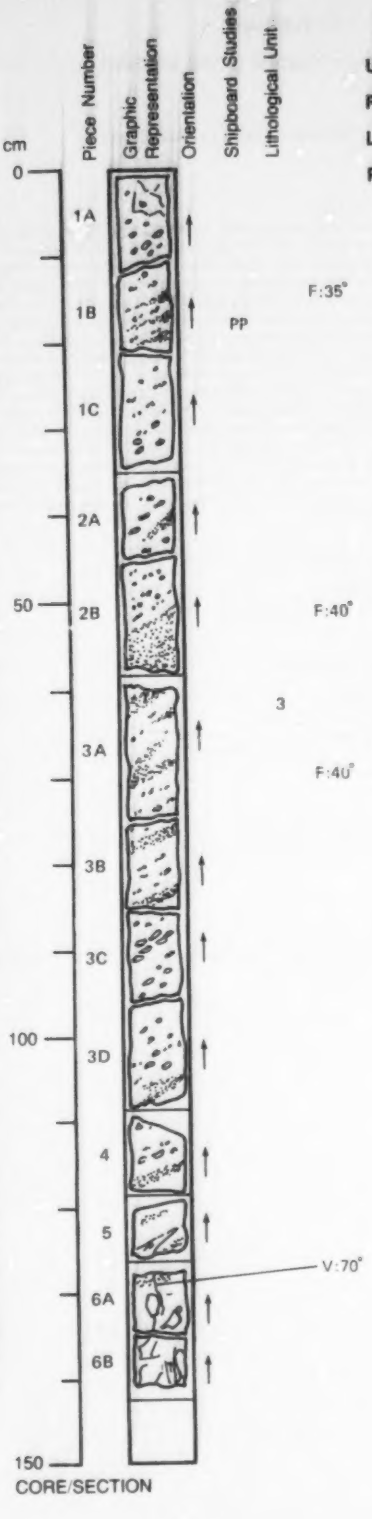
**Gabbro and Olivine Gabbro**

**Pieces 1-7**

**COLOR:** Light gray.
**LAYERING:** Several coarse- or very coarse- (i.e., 90-100 cm) to medium- or fine-grained zones. Changes are more gradual than others have been. Some may not be well defined. Where contacts are discernable, layers seem to dip into the core at about 10°. Olivine concentrations at 23, 65-85 93-97, 102-115, and 136-140 cm.
**DEFORMATION:** None
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 1-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Minor along fractures.

Clinopyroxene—Mode: 30%-50%.
Crystal size: 1-13 mm.
Crystal shape: Anhedral, sometimes subophitic.
Preferred orientation: None.
Percent replacement: Extensive amphibole replacement only near fractures.

Olivine—Mode: 0%-20%.
Crystal size: 2-30 mm, coarse-grained olivine occurs in olivine-rich zones at 93-97 and 136-140 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: In whole or partly replaced by talc-tremolite.
**SECONDARY MINERALOGY:**
Total percent: Various, concentrated along fractures.
Texture: Talc-tremolite after olivine throughout. Along fractures in Piece 7, complete pseudomorphs of olivine, green amphibole along fractures after clinopyroxene and some albitization of plagioclase.
Opaque-rich zones in Piece 5C and Piece 7—also pyrite here.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
2A
2B
3A
3B
3C
3D
4
5
6A
6B
F:35°
PP
F:40°
3
F:40°
V:70°
CORE/SECTION

### 118-735B-46R-1

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-6B

### Layered Olivine Gabbro and Olivine-Bearing Gabbro

### Pieces 1A-6B

**COLOR:** Gray, partly greenish gray.

**LAYERING:** Size and/or modal layering: Pieces 1A-5A (top), medium- (2-7 mm) and fine-grained (0.3-7 mm) layers alternating. Pieces 1A and 3C have coarse layers (5-20 mm). Thickness of each layer varies from 10 mm to 25 cm. Their boundaries are not sharp. Some layers thin out (Pieces 2A and 1B). Layer inclines 40° and is nearly parallel to the "magmatic" foliation. Pieces 6A and 6B: Coarse layer (20-30 mm) poor in olivine, more than 20 cm thick. Pieces 1A-1B are rich in olivine.

**DEFORMATION:** Almost none.

**PRIMARY MINERALOGY:**

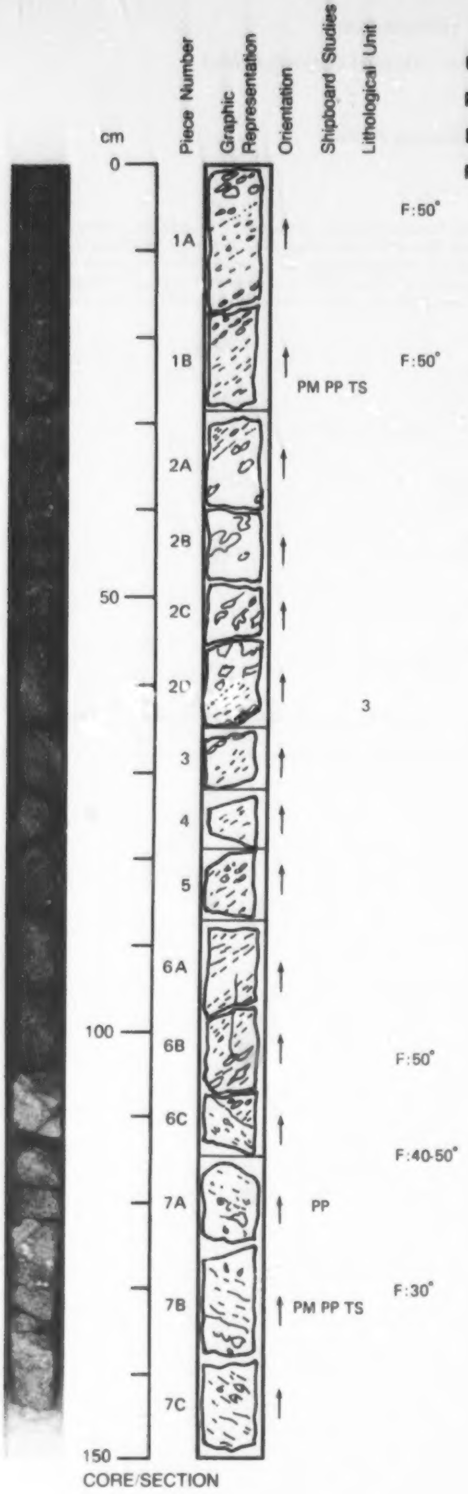
Plagioclase—Mode: 50%-65%.
Crystal size: Variable, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Marked, parallel to the layering.
Percent replacement: None.

Clinopyroxene—Mode: 50%-30%.
Crystal size: Variable, see above.
Crystal shape: Subhedral.
Preferred orientation: Marked.
Percent replacement: <3% by amphibole.

Olivine—Mode: 1%-8%.
Crystal size: Variable, see above.
Crystal shape: Anhedral.
Preferred orientation: Marked.
Percent replacement: Trace, oxidized partly.

**SECONDARY MINERALOGY:**

Total percent: <3%.
Texture: In Piece 1A, olivine is oxidated. Clinopyroxene replaced by amphibole (<3%).
Percent vein material: Trace.
Vein material. Amphibole veins (0.5-2 mm thick) are present in Pieces 1A, 6A, and 6B.



## 118-735B-46R-2

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-7C**

## Layered Olivine-Bearing Gabbro and Olivine Gabbro (+ Anorthosite)

**Pieces 1A-7C**

**COLOR:** Gray.

**LAYERING:** Marked size layering and modal layering. Piece 1A: 4 cm thick, coarse (10-30 mm), olivine: 5%, clinopyroxene: 40%, plagioclase: 55%. Pieces 1A-2A: 23 cm thick, medium (1-3 mm) and medium to coarse (3-10 mm), olivine: 10%, clinopyroxene: 35%, plagioclase: 55%. Pieces 2A-2D: 22 cm thick, coarse (10-40 mm) top: Olivine: 5%, clinopyroxene: 20%, plagioclase: 75%; bottom: olivine: 5%, clinopyroxenu 35%, plagioclase: 60%. Pieces 2A-4: 17 cm thick, fine to medium (0.5-3 mm) and medium to coarse (<10 mm), olivine: 7%, clinopyroxene: 38%, plagioclase: 55%, but there are some olivine-poor portions. Piece 5: 2 cm thick, coarse (10-20 mm), olivine: 2%, clinopyroxene: 38%, plagioclase: 60%. Pieces 5-6H: 8 cm thick, medium (2- mm), olivine: 3%, clinopyroxene: 37%, plagioclase: 60%. Piece 6A: 3 cm thick, coarse (>10 mm), olivine: 5%, clinopyroxene: 3%, plagioclase: 82% anorthosite layer. Pieces 6A-B: 5 cm thick, medium (3-8 mm), olivine: 6%, clinopyroxene: 37%, plagioclase: 55%. Piece 6B-C: >8 cm thick, coarse (10-30 mm), olivine: 2%, clinopyroxene: 38%, plagioclase: 60%. Layer boundaries are sharp. Inclination is approximatly 50° parallel to the foliation, which is indicated by marked shape preferred orientation of olivine, plagioclase, and clinopyroxene.

**DEFORMATION:** Pieces 1A-6C: None; Pieces 6C-7C: Strongly deformed. Foliation is defined by plagioclase-rich mylonitic bands and stretched clinopyroxene and olivine. Porphyroclasts of clinopyroxene have 5-10 mm grain size.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: Variable, see above.
Crystal size: Various, see above.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Marked parallel to layering.
Percent replacement: None.

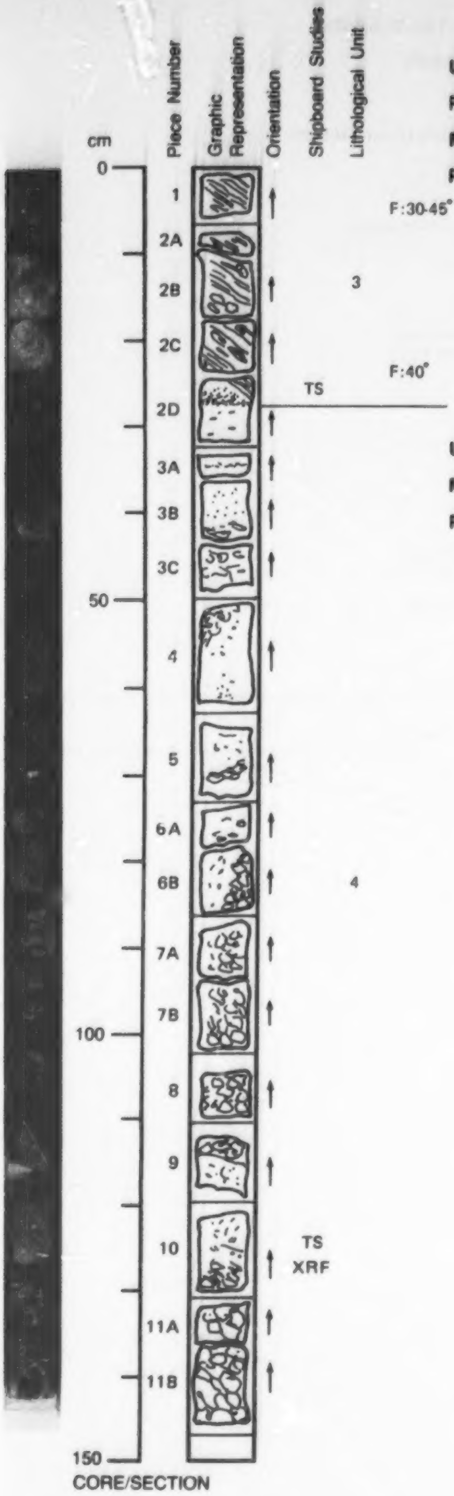
Clinopyroxene—Mode: Variable, see above.
Crystal size: Various, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Marked parallel to layering.
Percent replacement: <5% by amphibole.

Olivine—Mode: Variable, see above.
Crystal size: Various, see above.
Crystal shape: Anhedral.
Preferred orientation: Marked parallel to layering.
Percent replacement: <5% by amphibole + mica or talc.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Not determined.
Percent vein material: Trace.
Vein material: Amphibole vein in Pieces 6A and 6B.

**COMMENTS:** In Piece 6C, foliation due to deformation cut the "magmatic" foliation very sharply, inclining 40°-50°, but in the opposite direction.



### 118-735B-46R-3

## UNIT 3: OLIVINE GABBRO AND IRON-TITANIUM OXIDE GABBRO

### Pieces 1-11B

### Mylonitic to Porphyroclastic Metagabbro

### Pieces 1-2D (27 cm)

**COLOR:** Medium gray.
**LAYERING:** None.
**DEFORMATION:** Alternating mylonitic and porphyroclastic bands, inclining between 30° and 45°; clinopyroxene porphyroclasts up to 1 cm.
**PRIMARY MINERALOGY:** Difficult to estimate; probably corresponding to that of olivine-bearing gabbro (see Section 118-735B-46R-2).
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Olivine partially replaced by yellowish-brown mineral. Green amphibole replaces clinopyroxene. Partial sulfide dissemination.
Percent vein material: Not determined.
Vein material: Not determined.

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Massive Olivine-Bearing Gabbro

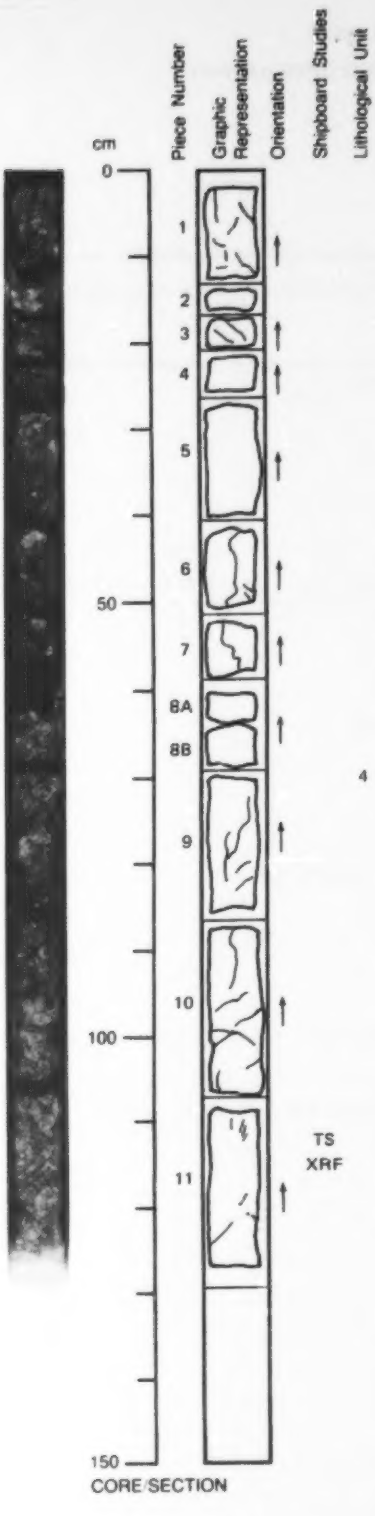
### Pieces 2D (27 cm)-11B

**COLOR:** Medium to dark gray.
**LAYERING:** Present, marked by grain-size variations throughout section (from fine-grained, <0.2 cm) to coarse-grained (up to 3 cm) and changes in phase proportions.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: <0.3 to 4 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <5% by amphibole.

Clinopyroxene—Mode: 35%-40%.
Crystal size: <0.2 to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Mostly fresh.

Olivine—Mode: <2%-10%, enriched in fine-grained portions.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Mostly fresh.

Ilmenite/Magnetite—Mode: Up to 8%.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Rock only slightly altered. Olivine is mostly fresh. Green amphibole replacement of clinopyroxene, <5%.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Ilmenite/magnetite enrichment in intervals 35-50, 75-115, and 130-145 cm.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5
6
7
8A
8B
9
10
11
4
TS
XRF
CORE/SECTION

**118-735B-46R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-11**

**Massive, Coarse-Grained, Iron-Titanium Oxide Gabbro**

**Pieces 1-11**

**COLOR:** Medium to dark gray.
**LAYERING:** There may be some faint primary layering.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%.
Crystal size: Up to 5 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 5 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <5%.

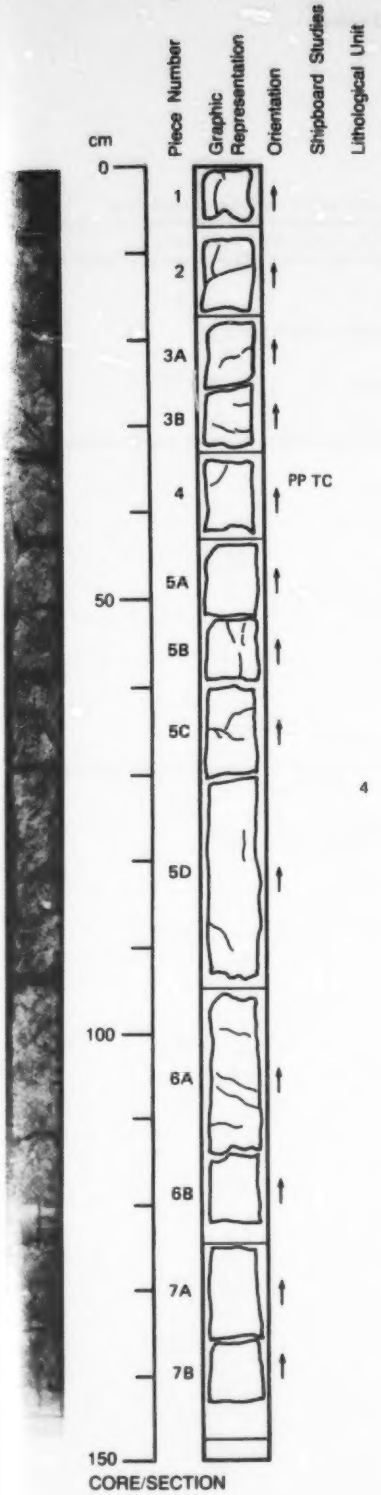
Olivine—Mode: <1%.
Crystal size: Up to 1 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Ilmenite/magnetite—Mode: 4%-15%.

Sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Rock appears to be fresh throughout section. Replacement of clinopyroxene by amphibole (<5%).
Percent vein material: Not determined.
Vein material: Minor veins and veinlets, mostly oxide and sulfide containing. Few veins and veinlets with green amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3A
3B
4
5A
5B
5C
5D
6A
6B
7A
7B
PP TC
4
CORE/SECTION

## 118-735B-47R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-7B**

**Massive, Coarse-Grained, Iron-Titanium Oxide Gabbro (Olivine-Bearing)**

**Pieces 1-7B**

**COLOR:** Medium to dark gray, locally greenish gray.
**LAYERING:** Not observed. Rock is more or less uniformly coarse-grained over entire length of section. Clinopyroxene and plagioclase are up to 5 cm across.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

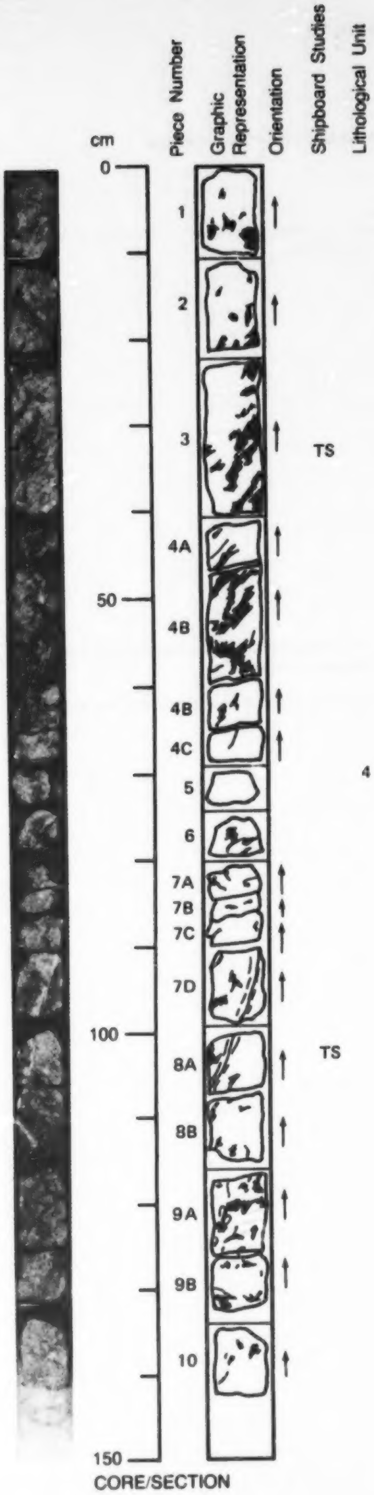
Plagioclase—Mode: 45%-50%.
Crystal size: Up to 5 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: Up to 5 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: <5%.

Olivine—Mode: 2%-5%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: In general, rock is relatively fresh. Only minor replacement of clinopyroxene by green amphibole (<5%). Sulfides disseminated throughout section.
Percent vein material: Not determined.
Vein material: Some veinlets with green amphibole. Also few veinlets with sulfides and oxides.



118-735B-47R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-10**

**Iron-Titanium Oxide Gabbro**

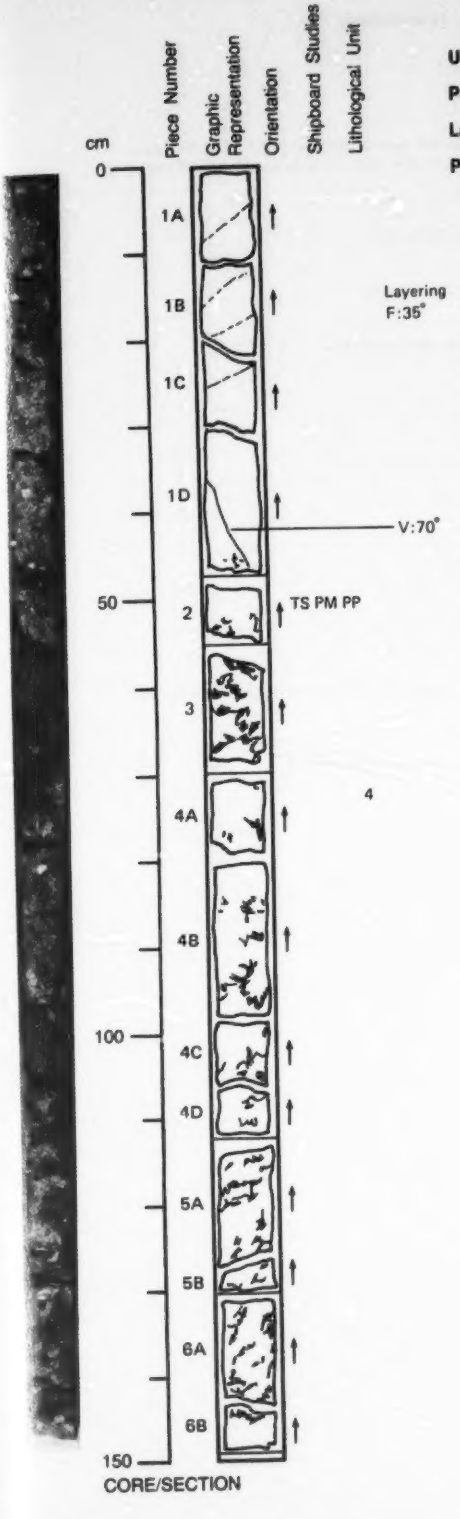
**Pieces 1-10**

**COLOR:** Gray to greenish gray, black in ore-rich patch (shown in graphic representation).
**LAYERING:** Possibly indicated by steeply dipping clinopyroxenes and crude orientation of oxide-rich zones. Rock very coarse-grained. No obvious size or phase segregation.
**DEFORMATION:** Amphibole/sodic-plagioclase fracturing; veining at approximately 70° from horizontal in Pieces 5-8.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 5%-55%.
Crystal size: Generally <1 cm; oikocrysts up to 5 cm in Pieces 1-3.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive.

Clinopyroxene—Mode: 30%-50%.
Crystal size: Generally <1 cm; phenocrysts up to 3 cm in Pieces 1-3, smaller downsection.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive.

Olivine—Mode: 0%-5%.
Crystal size: Not measured.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive to complete.

Ilmenite—Mode: 5%-50%.
Crystal size: <1 cm.
Crystal shape: Anhedral, rounded.
Preferred orientation: None.
Percent replacement: None.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole and sodic plagioclase in Pieces 5-8. Amphibole alteration approximately 5% pervasive in most rocks, even away from the fracture.
Percent vein material: Not determined.
Vein material: Amphibole, sodic plagioclase.
**COMMENTS:** Ilmenite-pyrite masses are shown as black on the core log.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
2
3
4A
4B
4C
4D
5A
5B
6A
6B
Layering
F:35°
V:70°
TS PM PP
4
CORE/SECTION

118-735B-47R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-6B

### Layered Olivine Gabbro

### Pieces 1A-1D

**COLOR:** Gray.

**LAYERING:** Modal layering, from the top to bottom. Piece 1A: 4 cm thick, olivine-poor (2%-3%); Pieces 1A-1B: 9 cm thick, olivine- and clinopyroxene-rich; olivine: 10%, clinopyroxene: 20%, plagioclase: 70%; Piece 1B: 5 cm thick, olivine-rich, clinopyroxene-poor, olivine: 25%, clinopyroxene: 15%, plagioclase: 60%; Pieces 1B-1C: 5 cm thick, plagioclase-poor, olivine-poor, olivine: 2%, clinopyroxene: 58%, plagioclase: 40%; Pieces 1C-1D: 20 cm thick, plagioclase- and olivine-rich, olivine: 20%, clinopyroxene: 20%, plagioclase: 60%. Grain size is fairly constant. No clear foliation and preferred orientation. Layers dip 35°. Layer contacts are gradational.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: $<5\%$ by amphibole.

Olivine—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: $<5\%$ by amphibole + talc or mica.

**SECONDARY MINERALOGY:**

Total percent: $<5\%$.
Texture: Amphibole replaces clinopyroxene and olivine.
Percent vein material: Trace.
Vein material: Amphibole vein, 1 mm thick, inclining 70° present in Piece 1A.

## 118-735B-47R-3 (continued)

### Iron-Titanium Oxide Gabbro

### Pieces 2-6B

**COLOR:** Gray, partly black and grayish.
**LAYERING:** Modal layering; 15-cm-thick, plagioclase-rich layer (plagioclase >95%, anorthositic) is present in Pieces 4A and 4B. Opaque minerals and mafic minerals are poor. Grain size is constant (10-30 mm).
**DEFORMATION:** Weak-none.
**PRIMARY MINERALOGY:**

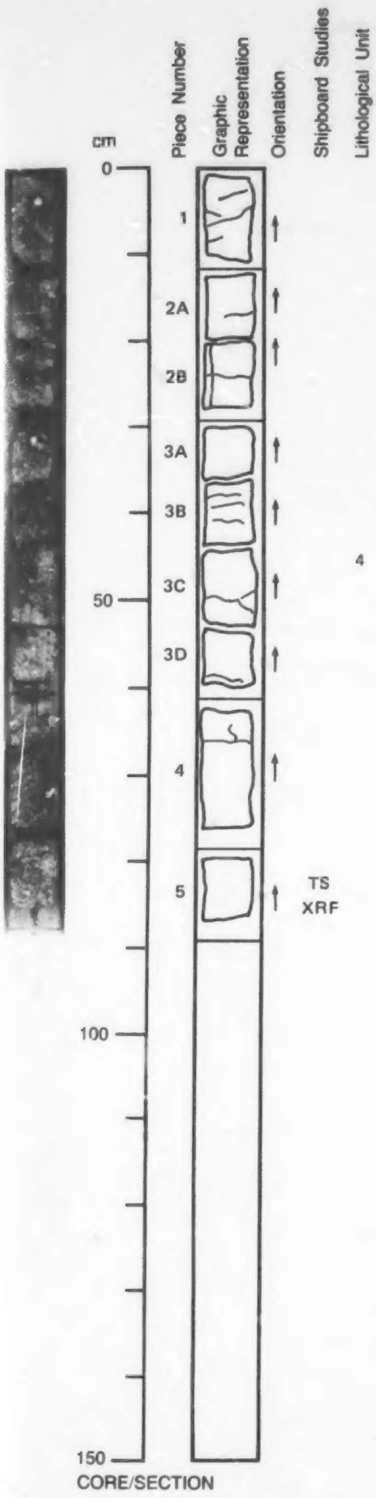
Plagioclase—Mode: 60%, except for anorthositic layer.
Crystal size: 10-30 mm.
Crystal shape: Subhedral.
Preferred orientation: Weak shape preferred orientation.
Percent replacement: None.

Clinopyroxene—Mode: 20%-30%, except for anorthositic layer.
Crystal size: 10-30 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Weak.
Percent replacement: <30% by amphibole.

Olivine—Mode: <2%.
Crystal size: 10-30 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Opaque mineral—Mode: 10%-20%.
Crystal size: 10-30 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: None.

**SECONDARY MINERALOGY:**
Total percent: <15%.
Texture: Clinopyroxene is replaced by amphibole up to 15% in total mode. Olivine is also replaced by amphibole.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Olivine is poor in the opaque-rich, iron-titanium oxide gabbro.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
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1
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3C
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TS
XRF
4
CORE/SECTION

**118-735B-47R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-5**

**Massive, Coarse- to Medium-Grained, Olivine Gabbro (Enriched in Iron-Titanium Oxides).**

**Pieces 1-5**

**COLOR:** Medium gray.
**LAYERING:** There may be some faint primary layering; slight grain-size variation from coarse-grained (on average 1-2 cm) to medium-grained (<1 cm).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: Up to 4 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

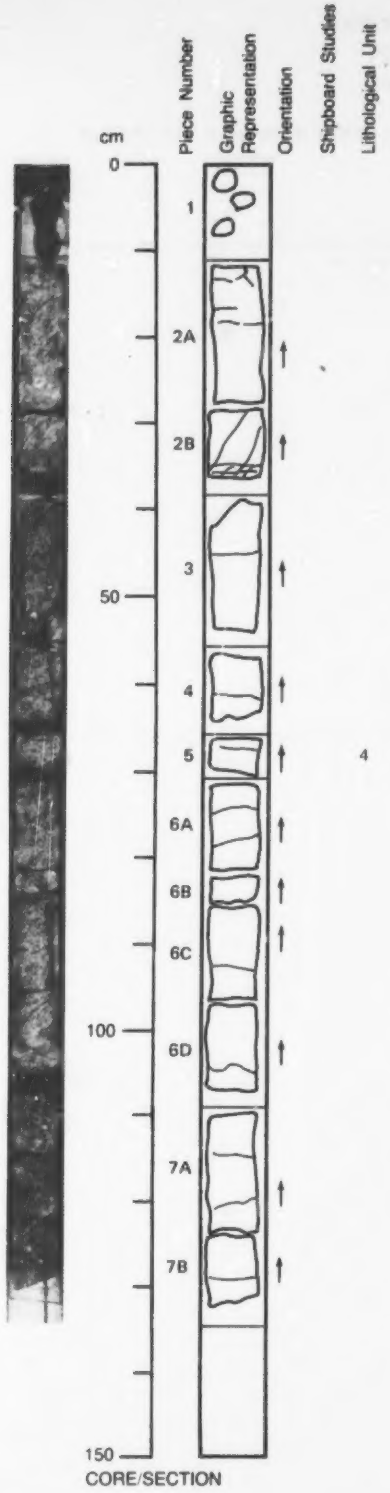
Olivine—Mode: 2%-8%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 3%-6%.

Primary sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**

Total percent: <3%.
Texture: Rock is fresh throughout section. Olivine is almost completely fresh. Clinopyroxene replacement by green amphibole.
Percent vein material: Few veinlets.
Vein material: Not determined.



**118-735B-48R-1**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1-7B

### Iron-Titanium Oxide-Rich Gabbro

### Pieces 1 and 3-7B

**COLOR:** Medium to dark gray.
**LAYERING:** Faint magmatic foliation on some pieces, otherwise none.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 2.5 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene: Mode: 40%.
Crystal size: Up to 2 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Partially replaced by green amphibole.

Iron-titanium oxides—Mode: 10%-20%, interstitial.

Olivine—Mode: <2%.

Sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: Green amphibole partially replacing clinopyroxene.
Percent vein material: Few veins and veinlets.
Vein material: Green amphibole, veinlets with white mineral.
**COMMENTS:** Primary minerology is difficult to estimate reliably. Ore-rich zone starts at the very bottom of Piece 2B.

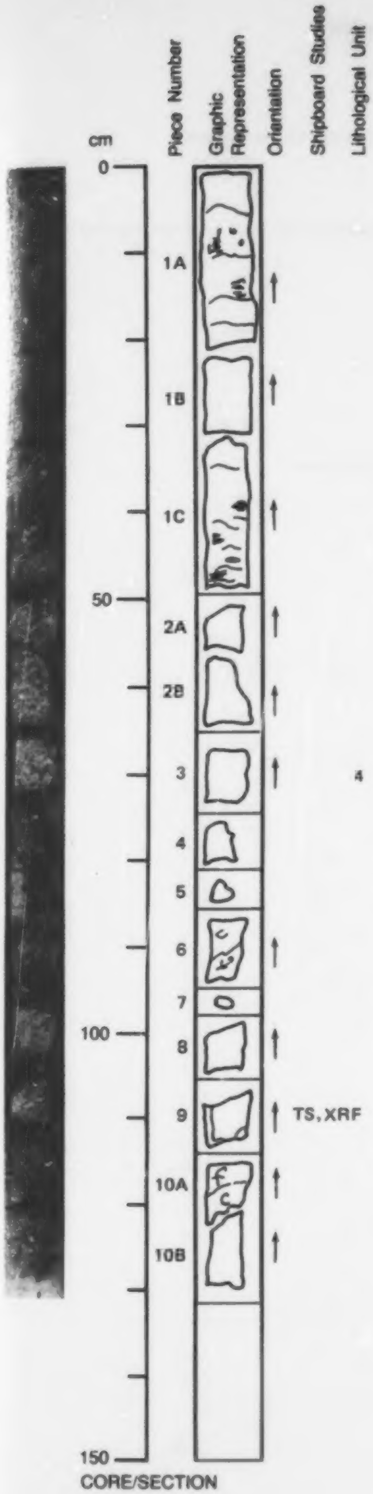
### Massive, Medium- to Coarse-Grained, Olivine Gabbro

### Pieces 2A and 2B

**COLOR:** Light gray.
**LAYERING:** None—uniform grain size of about 1 cm.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%.
Crystal size: 1 cm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Mostly fresh.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Olivine mostly fresh. Few sulfides.
Percent vein material: Few veinlets.
Vein material: Amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
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10A
10B
TS, XRF
4
CORE/SECTION

### 118-735B-48R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-10B**

### Ilmenite-Bearing Gabbro

**Pieces 1A-10B**

**COLOR:** Gray.
**LAYERING:** None apparent. Gradual change in grainsize as noted below. Sharp contacts in Pieces 6 and 10A.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 10.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 1%-2% by chlorite.

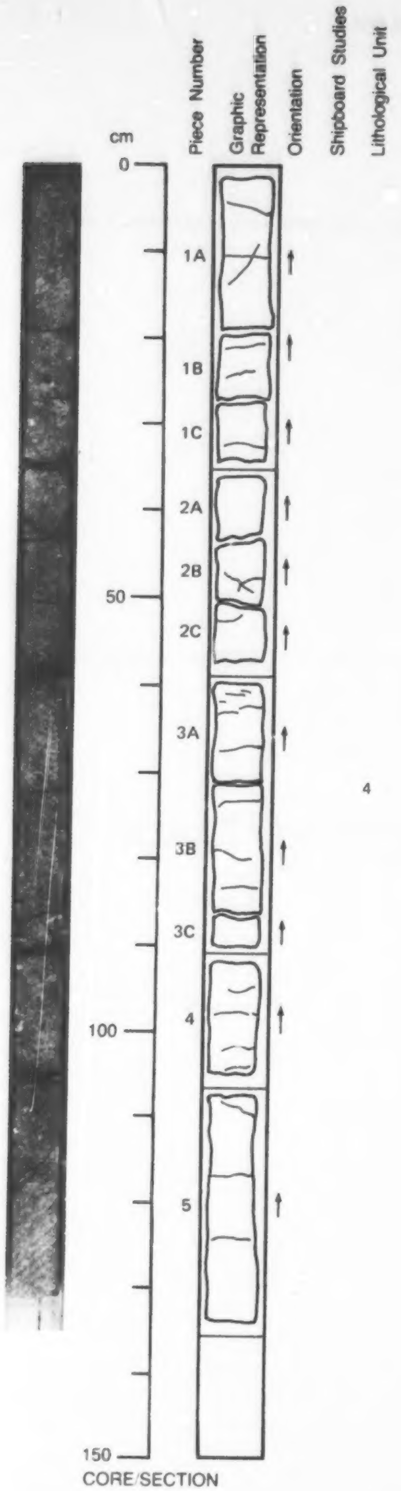
Clinopyroxene—Mode: 40%-45%.
Crystal size: 0.5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Olivine—Mode: 2%.
Crystal size: 2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <1% by talc or clay.

Ilmenite—10%-20%.
Crystal size: Not determined.
Crystal shape: Anhedral aggregates, concentrated in interstitial area; fine-grained mixed with 1% disseminated sulfide.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: 3%.
Texture: Not determined.
Percent vein material: 2%.
Vein material: Amphibole.

**COMMENTS:** Pieces 1A-1C and 2A-2B are coarse-grained and contain 10%-15% oxides + sulfides. There is a gradual decrease from Piece 1A to Piece 10A in both grain size and ore minerals. Pieces 7-8 are fine-grained and relatively barren.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1A
1B
1C
2A
2B
50
2C
3A
3B
3C
4
100
5
150
4
CORE/SECTION

118-735B-48R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-5**

**Massive, Medium- to Coarse-Grained, Iron-Titanium Oxide Gabbro**

**Pieces 1A-5**

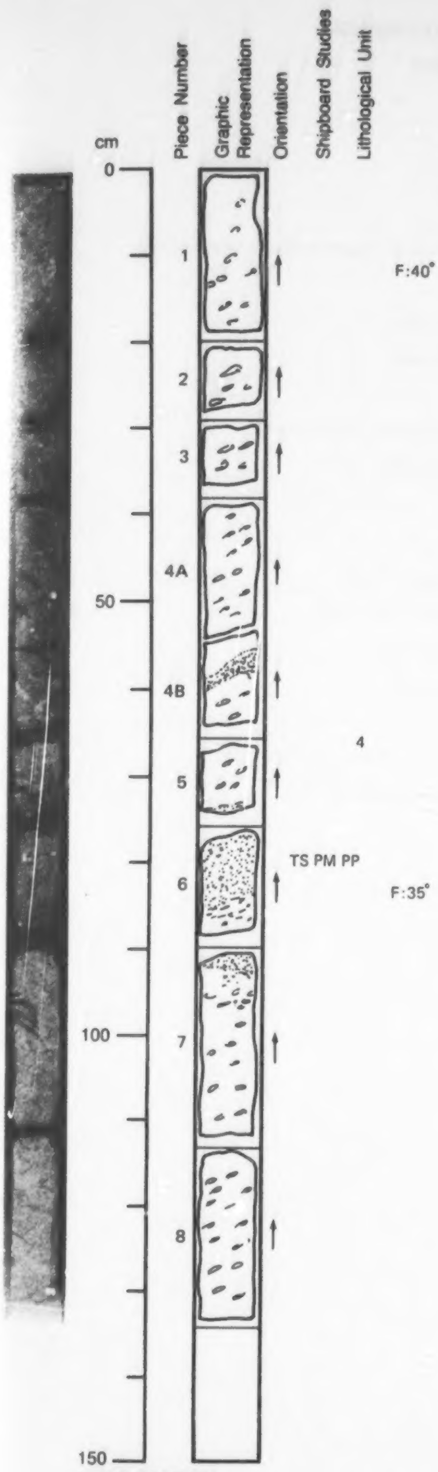
**COLOR:** Medium to dark gray.
**LAYERING:** None. Grain-size varying between medium- (average 0.8 cm) and coarse-grained (1.5 cm).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: <10% ~ by green amphibole.

Olivine—Mode: <2%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: <8%-10%.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Clinoyroxene partially replaced by green amphibole.
Percent vein material: Few veins and veinlets.
Vein material: Not determined.

**118-735B-48R-4**



## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-8**

**Iron-Titanium Oxide-Rich Metagabbro**

**Pieces 1-8**

**COLOR:** Gray, speckled with black.
**LAYERING:** Size layering and modal layering. In Pieces 4B and 5, 1.5- and 12-cm-thick, fine- to medium-grained layers are present. Grain-size is 1-3 mm. Other part is coarser than this, ranging 3-8 mm. Opaque minerals are poor in upper part of Piece 5 (5%). Foliation is defined by elongate plagioclase: clinopyroxene is parallel to the layering.
**DEFORMATION:** Not marked.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: Various, see above.
Crystal shape: Euhedral.
Preferred orientation: Marked.
Percent replacement: None.

Clinopyroxene—Mode: 30%.
Crystal size: Various, see above.
Crystal shape: Subhedral.
Preferred orientation: Marked.
Percent replacement: 20%-70% by amphibole.

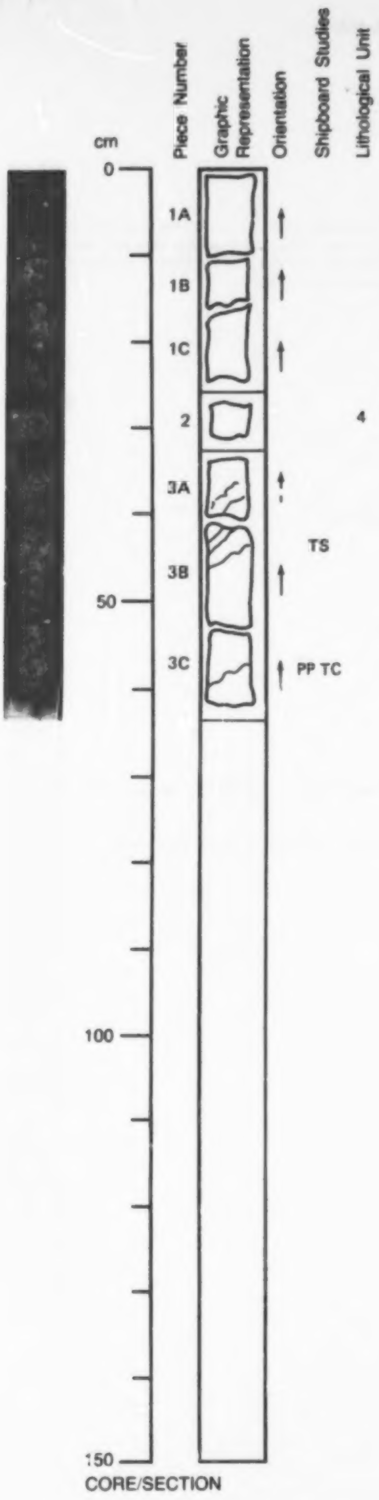
Olivine—Mode: >2%.
Crystal size: Various, see above.
Crystal shape: Anhedral.
Preferred orientation: No observation.
Percent replacement: Up to 50%, by clay(?)

Opaque—Mode: 10%-20%.
Crystal size: Various.
Crystal shape: Anhedral.
Preferred orientation: Marked.
Percent replacement: None.

**SECONDARY MINERALOGY:**

Total percent: 10%-15%.
Texture: Amphibole replacing clinopyroxene. Olivine is replaced by dark green mineral (clay?).
Percent vein material: None.
Vein material: None.

**COMMENTS:** Many sulfides are present, especially in iron-titaniuim oxide aggregates.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1A
1B
1C
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3A
3B
TS
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3C
PP TC
100
150
CORE/SECTION

118-735B-49R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-3C**

**Ilmenite-Bearing Gabbro**

**Pieces 1A-3C**

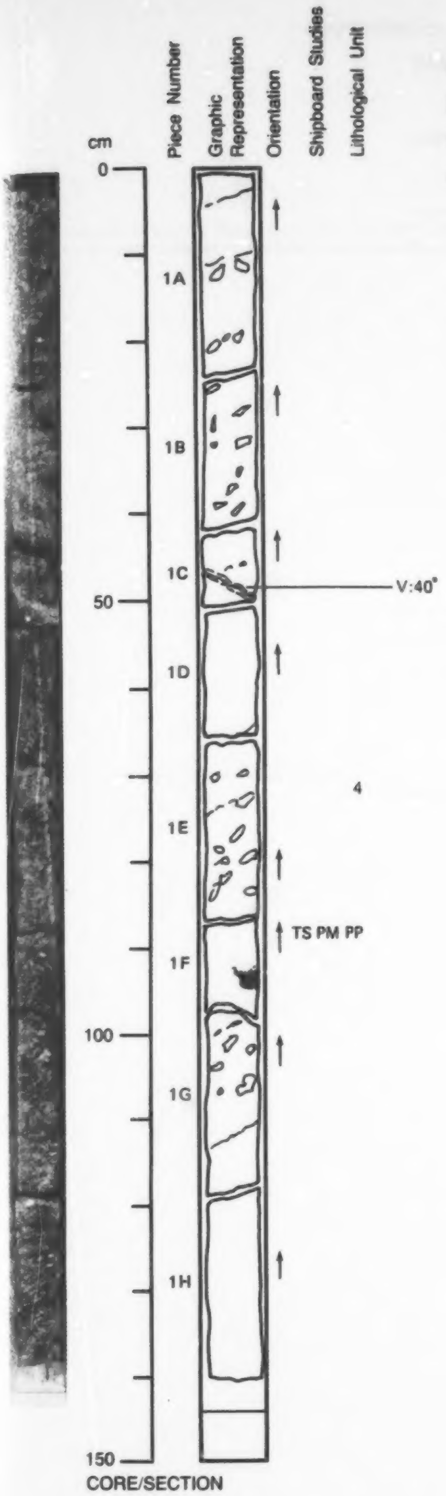
**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Faint foliation in Pieces 3A-3C, foliated areas have finer grain size.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral (discrete grains, not oikocrysts).
Preferred orientation: None.
Percent replacement: 5% by amphibole.

Olivine—Mode: 1%-3%.
Crystal size: 0.2-1 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Preferred replacement: 90% replaced by clay.

Ilmenite—Mode: 15% (mixed with <1% sulfide).
Crystal size: Not determined.
Crystal shape: Interstitial, fine-grained.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: 8%-10%.
Texture: Green amphibole replacing clinopyroxene (up to 5%).
Percent vein material: 2%.
Vein material: Very small white veins, possibly albite.



## 118-735B-49R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-1H

### Iron-Titanium Oxide-Rich Metagabbro

### Pieces 1A-1H

**COLOR:** Greenish gray; speckled with black.

**LAYERING:** Slight change in grain-size indicates size layering.

Pieces 1B, 1E, and 1G contain coarse-grained clinopyroxene (10-25 mm); other part is 5-15 mm.
No marked foliation. Abundance of opaque minerals varies and shows modal layering.

**DEFORMATION:** Not marked.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: Various.
Crystal shape: Subhedral.
Preferred orientation: Not clear.
Percent replacement: Partly replaced by sodium-rich plagioclase.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Various, see above.
Crystal shape: Euhedral.
Preferred orientation: Not clear.
Percent replacement: 10% by amphibole.

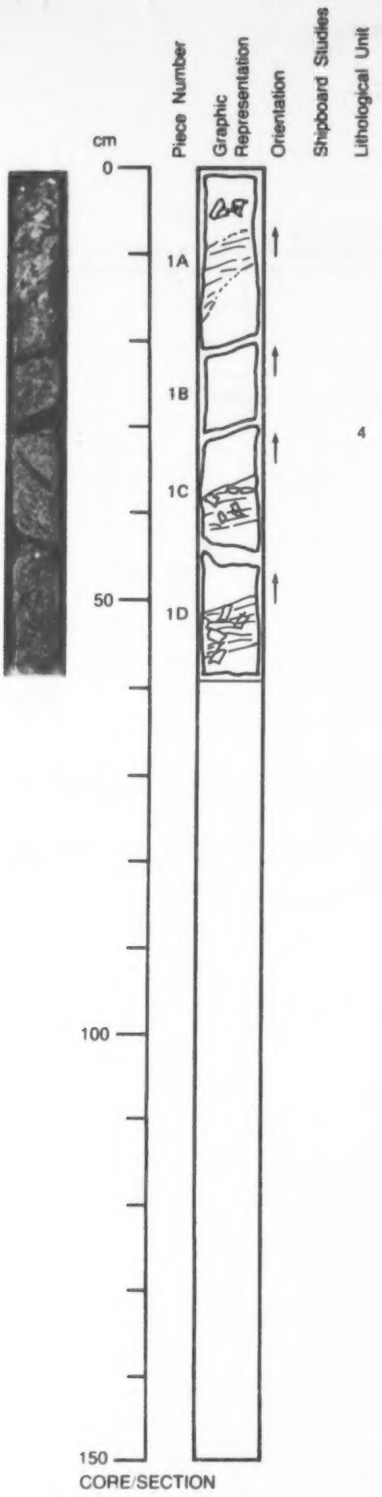
Olivine—Mode: <2%.
Crystal size: Various, or absent.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: Up to 50% by clay.

Iron-titanium oxides—Mode: Various, 1%-15%.
Crystal size: Various.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 15%.
Texture: Clinopyroxene is replaced by amphibole (10%-20%). Olivine is replaced by dark green mineral (clay or chlorite?; 1%). Albitized part in Piece 1C, 1-2 cm thick, 60° inclination.
Percent vein material: None.
Vein material: None.

**COMMENTS:** The abundance of opaque minerals is variable. Pieces 1A, 1B, 1C, 1E, and 1G are opaque-poor, <2%.



**118-735B-49R-3**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1D**

**Iron-Titanium Oxide-Bearing Metagabbro**

**Pieces 1A-1D**

**COLOR:** Greenish-gray; speckled with black.

**LAYERING:** Grain size and modal layering. Pyroxene crystal size is bigger in Piece 1A (top) and Piece 1C (middle) than other parts. Iron-titanium oxide is abundant in middle of Piece 1A, middle of Piece 1C, and Piece 1D.

**DEFORMATION:** Not marked.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%-75%.
Crystal size: 5-25 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: None.

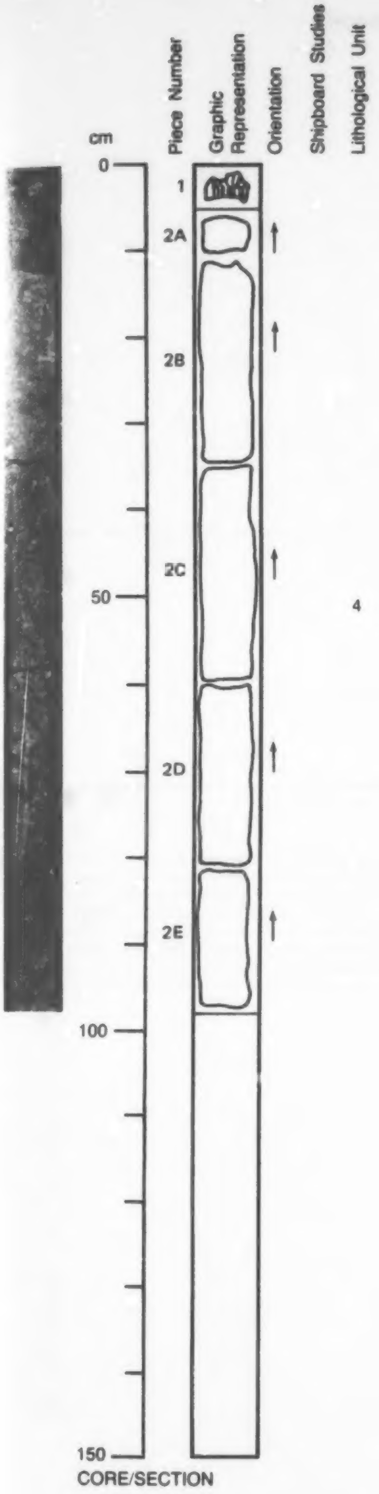
Clinopyroxene—Mode: 20%-35%.
Crystal size: 5-25 mm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: 10%-50% by amphibole.

Olivine—Mode: <2%.
Crystal size: 5-25 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Replaced by clay.

Iron-titanium oxides: Mode: 2%-15%.
Crystal size: 5-25 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

**SECONDARY MINERALOGY:**

Total percent: 5%-20%.
Texture: Amphibole replacing clinopyroxene—5%-15% in total modal abundance. Olivine is replaced by dark green mineral (chlorite or clay?).
Percent vein material: None.
Vein material: None.



**118-735B-50R-1**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1-2E

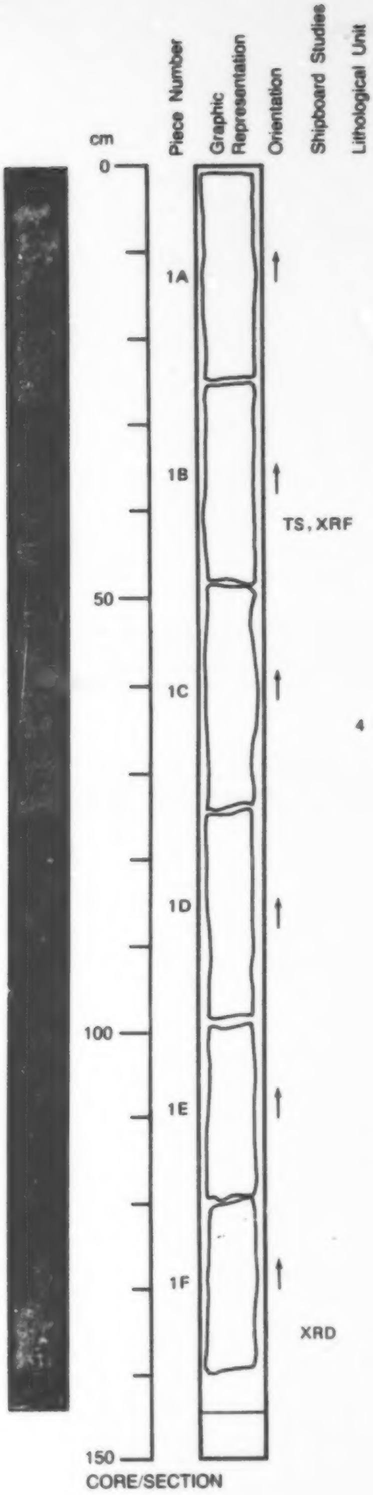
### Ilmenite-Bearing Gabbro

### Pieces 1A-2E

**COLOR:** Gray.
**LAYERING:** No obvious primary layering.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 48%.
Crystal size: 0.5-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 0.5-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Ilmenite—Mode: 12%.
Crystal size: 3-4 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: Not determined.
Percent replacement: 0%.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Amphibole replacement of clinopyroxene and filling minute fractures, which crosscut clinopyroxene and plagioclase. Concentrations of ilmenite are equivocal as to whether secondary or primary, but in this section appear to be associated with amphibole. Traces of sulfides occur as inclusions in clinopyroxene and plagioclase and in thin veins/fractures of green amphibole.
Percent vein material: Very thin fractures.
Vein material: Amphibole.
**COMMENTS:** Section is very coarse-grained. Clinopyroxene looks like it has intercumulus growth on cumulus crystals, but texture is not subophitic. Piece 1 is a highly oxidized, mylonitized, porphyroclast metagabbro. Feldspar totally albitized. Probably knocked off from somewhere uphole—not consistent with the mineralogy of this section. All identified oxide minerals not ilmenite, some magnetite.



## 118-735B-50R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1F**

**Iron-Titanium Oxide Gabbro**

**Pieces 1A-1F**

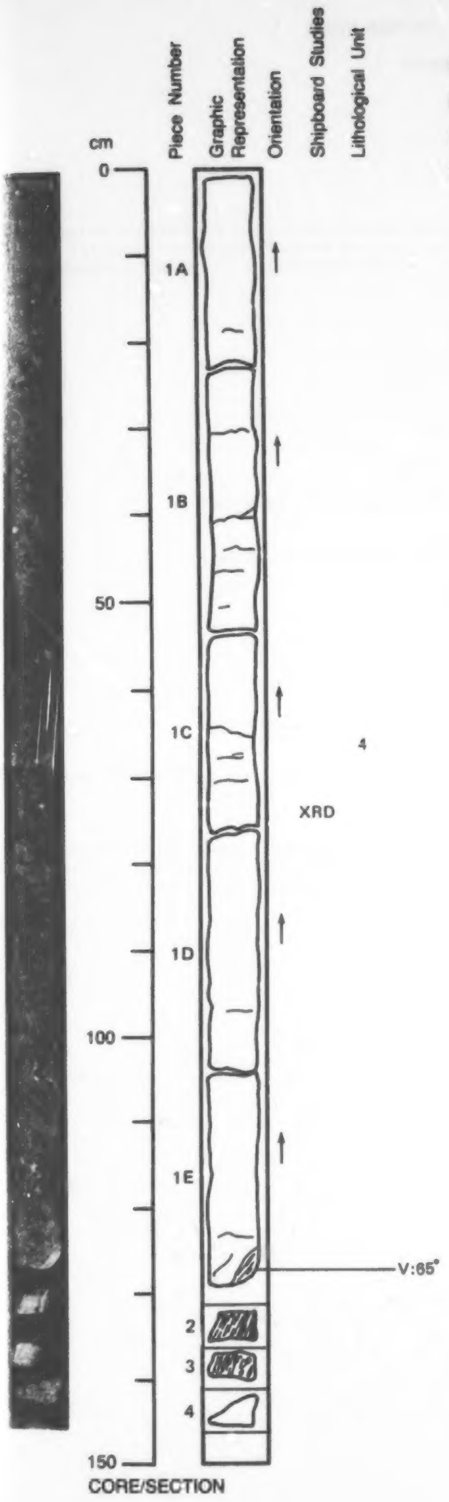
**COLOR:** Gray-black.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 35%-60%.
Crystal size: 0.4-2 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-30%.
Crystal size: 0.2-3 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: 60% by amphibole.

Ilmenite/magnetite*—Mode: 10%-45%.
Crystal size: 0.1-4 mm.
Crystal shape: Anhedral interstitial, often enclosing silicates and as round inclusions in silicates.
Preferred orientation: None determined
Percent replacement: None or very little.

Olivine—Mode: 0.5%.
Crystal size: 0.2-0.6 cm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: 80% by talc + tremolite.

Sulfides—Mode: 0.1%-1.0%.
**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Generally, the plagioclase is fresh and clear, while the pyroxene is variously replaced by green amphibole, but is quite fresh locally.
Percent vein material: No macroscopic veins.
Vein material: Not determined.
**COMMENTS:** Equigranular texture with interstitial magnetite enclosing subhedral to anhedral plagioclase and pyroxene. Both magnetite and sulfides occur as round inclusions in pyroxene and plagioclase. Alteration: The entire section is remarkably free of joints and through-going fractures. There does not appear to be any relationship between alteration and the abundance of the oxides. This, the volume of iron-titanium oxides, the overall low degree of alteration, and the numerous inclusions of magnetite and sulfide in unaltered pyroxene and plagioclase, indicate an igneous, not hydrothermal paragenesis for the oxides.
*The rock will suspend a magnet in the air, supporting the hypothesis that part of the oxides is magnetite.



## 118-735B-50R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-4

### Iron-Titanium Oxide-Bearing Gabbro

### Pieces 1A-4

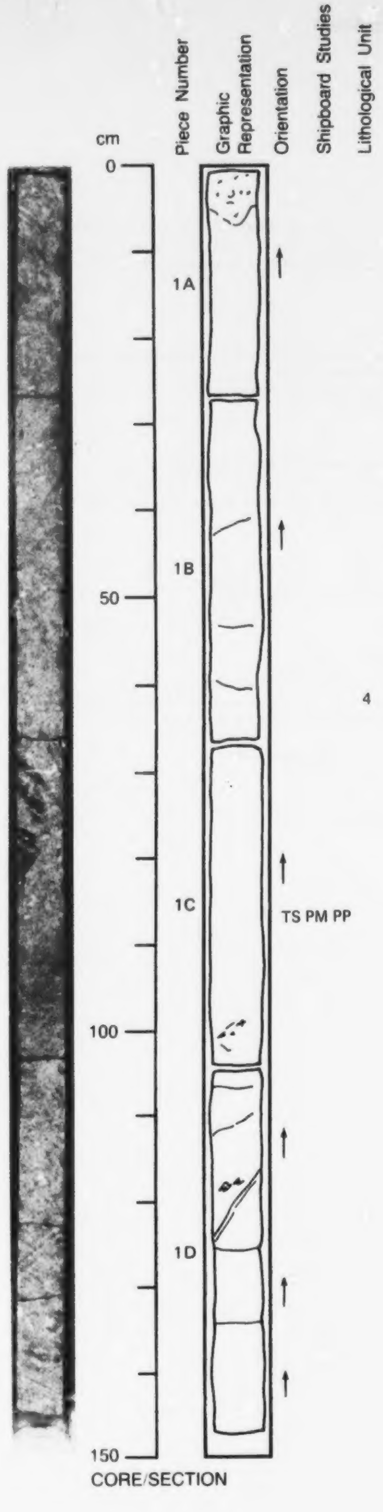
**COLOR:** Gray.
**LAYERING:** Very well-defined, coarse- to medium-grained size transitions—at least two full cycles; 50-0 cm, 110-45 cm, relatively sharp transitions coarse-fine, fine-coarse at 17, 45, 63, and 108 cm.
**DEFORMATION:** Sheared brecciated zone at 120-140 cm. Several subhorizontal brittle fractures cut core.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-40%.
Crystal size: 2-18 mm.
Crystal shape: Euhedral (in smaller grains partially enclosed by clinopyroxene) to anhedral.
Preferred orientation: Weak lamination dipping 30°-40°.
Percent replacement: Fresh to slightly green with amphibole.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-30 mm.
Crystal shape: Near euhedral to anhedral, must be in part primocrysts.
Preferred orientation: Weak lamination dipping 30°-40°.
Percent replacement: Replaced by amphibole in increasing degree downward near deformed zone.

Iron-titanium oxides—Mode: 20%, variable.
Crystal size: 2-10 mm.
Crystal shape: Anhedral, with some pyrite interstitial to pyroxene.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: Various, nearly 100% near shear zone.
Texture: Amphibole after pyroxene in increasing degree toward the shear zone—some pyrite filling fractures in pyroxene. A 2-cm-wide, feldspathic vein cuts core through shear at 130-140 cm. Sample below that is amphibolitized and broken. Vein has a granular texture.
Percent vein material: Not determined.
Vein material: Pieces 2-3: 4-cm-wide albitized vein dips at 65°.
**COMMENTS:** Opaque phase is strongly magnetic—magnetite at least in part.



**118-735B-50R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces: 1A-1D**

**Iron-Titanium Oxide Gabbro**

**Pieces 1A-1D**

**COLOR:** Gray.

**LAYERING:** Defined by coarse-medium size variations. Olivine occurs in thin zones at 100 and 120 cm.

**DEFORMATION:** A little alteration on top 5 cm—continuous with shear zone in Section 118-735B-50R-3. Thin section shows slight deformation and the development of neoblasts of plagioclase in sample at 84-87 cm.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-50%.
Crystal size: 2-18 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Igneous lamination.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-30 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Igneous lamination.
Percent replacement: Various, highest near veins by green amphibole.

Olivine—Mode: Not determined.
Crystal size: 1 cm large cyrstals cut surface of bottom of Piece 1C.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

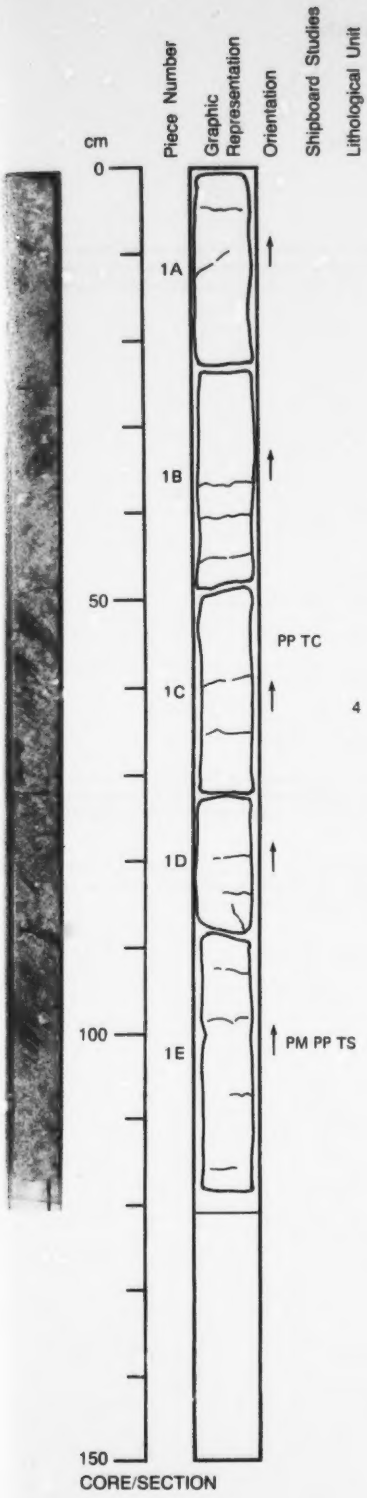
Ilmenite/magnetite—Mode: Up to 20%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 5%-15%.
Texture: A green amphibole commonly replaces clinopyroxene, particularly near veins. There is a patch of albitic plagioclase on the top of Piece 1A.
Percent vein material: Not determined.
Vein material: Amphibole-filled vein at 120 cm.

**COMMENTS:** Similar to Section 118-735B-50R-3. The entire section shows a district parallel orientation of clinopyroxene, particularly the larger ones. This is best shown at 50-60 cm. Thin section shows slight deformation and the development of neoblasts of plagioclase in sample at 84-87 cm.

best copy available



## 118-735B-51R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-1E

### Iron-Titanium Oxide-Bearing Gabbro

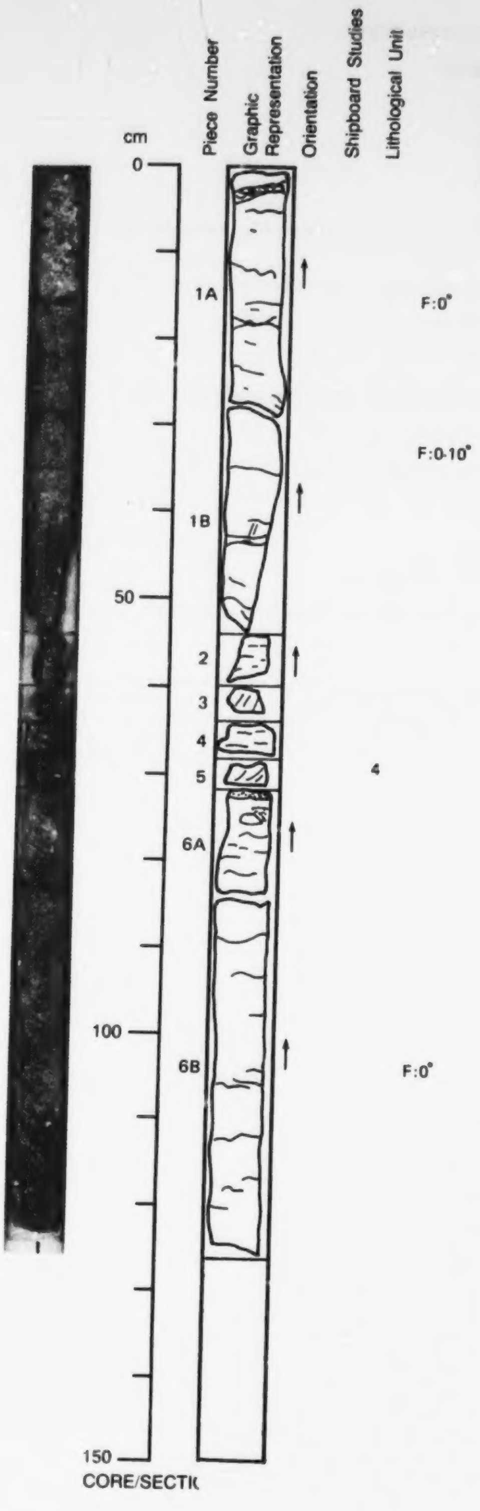
### Pieces 1A-1E

**COLOR:** Gray.
**LAYERING:** Possible primary layering defined by alternating coarse to very coarse grain sizes.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Variable, average 55%-60% estimated original mode.
Crystal size: 5-20 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: 15%-20%.

Clinopyroxene—Mode: Variable, average 40%-45% estimated original mode.
Crystal size: 1-18 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: 40%-50% by amphibole.

Olivine—Mode: Trace (Piece 1E).
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 100% by amphibole.

Iron oxides—Mode: Presently make up 20% of the rock, but unclear whether secondary or primary.
**SECONDARY MINERALOGY:**
Total percent: 15%-20%.
Texture: Amphibole constitutes 10%-15% of rock, replacing primary phases along grain boundaries and in very thin fractures. Numerous very thin, nearly horizontal fractures are filled by white mineral. Iron oxides are concentrated in masses at grain boundary edges and appear to be associated with some amphibole veinlets. Amphibole generally occurs around the oxides, between them and the primary phases, clinopyroxene and plagioclase. Trace amounts of sulfides throughout.
Percent vein material: Not determined.
Vein material: Green amphibole.



## 118-735B-51R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-6B

### Olivine and Iron-Titanium Oxide-Bearing Gabbros

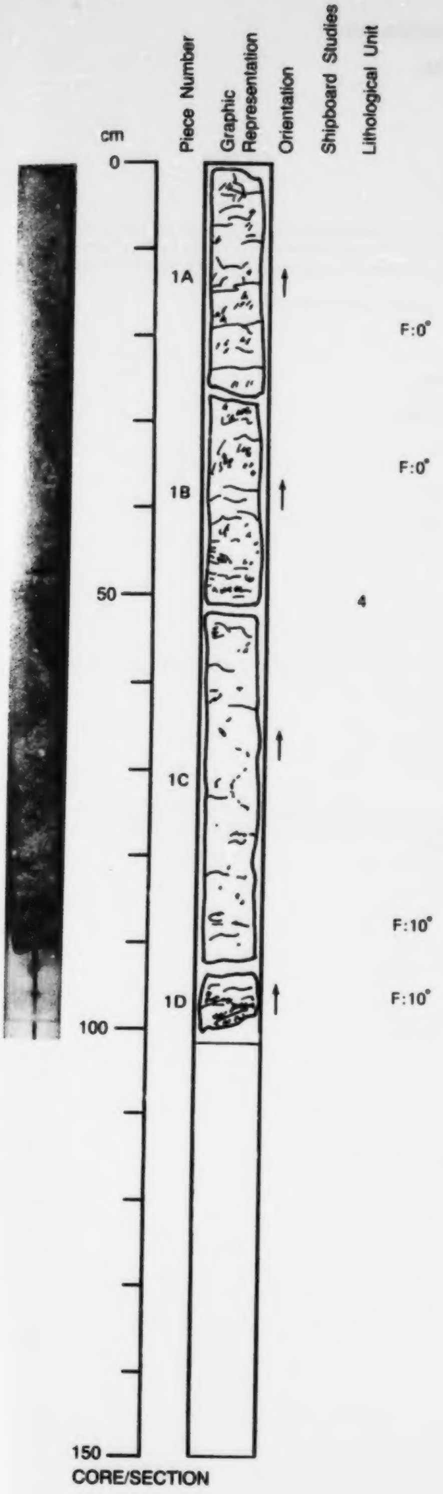
### Pieces 1A-6B

**COLOR:** Dark gray.
**LAYERING:** None apparent.
**DEFORMATION:** Evident in Piece 1B where locally porphyroclastic gabbro develops. The grain size decreases from up to 13 mm in less-deformed gabbro to less than 10 mm and generally less than 5 mm. Many subhorizontal cracks are present; some are filled by white mineral.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Weak.
Percent replacement: Moderate.

Clinopyroxene—Mode: 40%-50%.
Crystal size: <1-13 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Moderate.

Olivine—Mode: <1%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: Not determined.
Percent replacement: Moderate.

Iron-titanium oxides—Mode: 5%-15%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <25%.
Texture: Green amphibole partially replaces clinopyroxene or fills less than 1-mm-thick veinlets in plagioclase and pyroxene. Olivine is replaced by magnetite (black), talc (gray green), and chlorite (?, black). Sulfide streaks are present throughout the section associated with black oxides and surrounding silicates.
Percent vein material: Not determined.
Vein material: Sulfides and amphiboles. In Piece 1A (top), a plagioclase (?) and amphibole vein cuts the core. There is amphibolitization of the walls of the vein. Walls of steeply dipping crack are filled with hydroxides and blue soapy, but hard, mineral.



**118-735B-51R-3**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1D**

**Iron-Titanium Oxide-Bearing Gabbro**

**Pieces 1A-1D**

**COLOR:** Dark gray.
**LAYERING:** Not apparent.
**DEFORMATION:** There is a flat foliation throughout the section. The black oxides are preferentially found in these structures.
**PRIMARY MINERALOGY:**

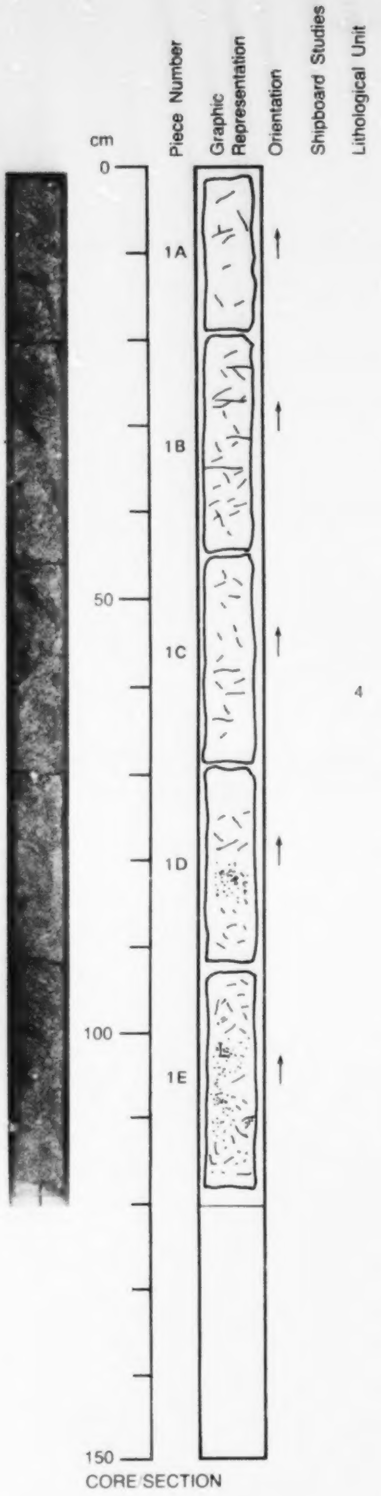
Plagioclase—Mode: 50%-60%.
Crystal size: <1 mm.
Crystal shape: Not determined.
Preferred orientation: Visible.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: <1 mm.
Crystal shape: Not determined.
Preferred orientation: Visible.
Percent replacement: Moderate.

Olivine—Mode: Traces.
Crystal size: <1 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: Visible.
Percent replacement: Extensive.

Iron-titanium oxides—Mode: 5%-15%.
Crystal size: Not determined.
Crystal shape: Discontinuous layer 13 mm thick.
Preferred orientation: Strong.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: <50%.
Texture: Pseudomorphic. Clinopyroxene is partly replaced by amphiboles. Olivine is replaced by black chlorite. Plagioclase is sometimes milky (replaced by clays or chlorite?). Sulfides are disseminated throughout the section, associated with ilmenite, amphibole veinlets, chalcopyrite, and pyrite.
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole. Small veinlets are filled by plagioclase and green amphiboles. These have more amphibole-rich walls.



**118-735B-51R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1E**

**Iron-Titanium Oxide Gabbro**

**Pieces 1A-1E**

**COLOR:** Gray.

**LAYERING:** Some coarse to fine variation—very coarse-grained at 75 cm (2 cm crystals) to medium-grained at 50 cm. Top of core is uniformly medium-grained with a lamination of pyroxene dipping 25°—bottom piece is interfingered fine- and medium-grained material. Olivine-rich layers at 16 and 73 cm.

**DEFORMATION:** None apparent—unless lamination is not all primary.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-60%.
Crystal size: 1-10 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

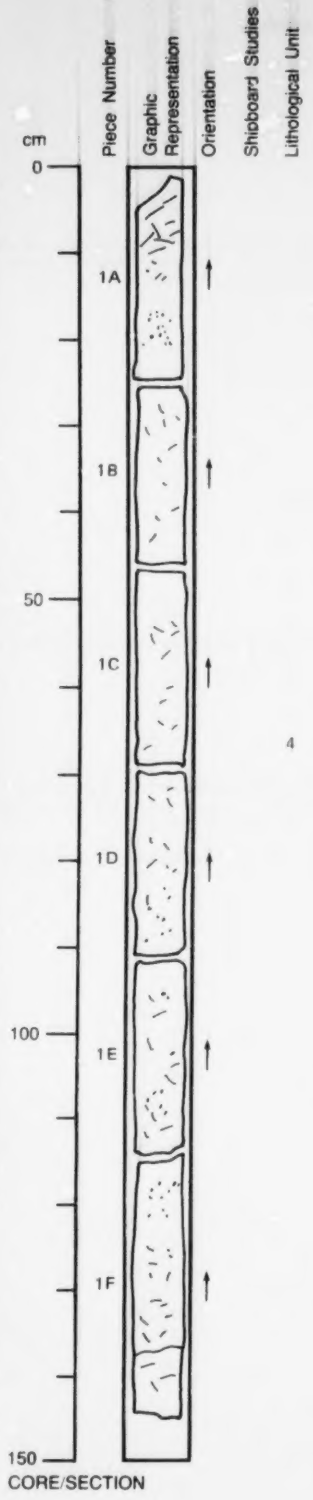
Clinopyroxene—Mode: 40%-55%.
Crystal size: 1-18 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: 25° dipping lamination.
Percent replacement: Minor replacement by amphibole.

Olivine—Mode: Up to 2%; very uncommon.
Crystal size: 6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Variously to talc-tremolite.

Ilmenite/magnetite—Mode: Up to 15%, decreasing somewhat downcore, similar in both coarse and fine sections.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Minor.
Texture: Minor amphibolitization of clinopyroxene. Veins are minor, usually subhorizontal, and have feldspathic (?) fill. There is a trace of fine pyrite disseminated in section. Some olivine has been replaced by talc/tremolite.
Percent vein material: Not determined.
Vein material: Feldspar (?).



## 118-735B-52R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-1F**

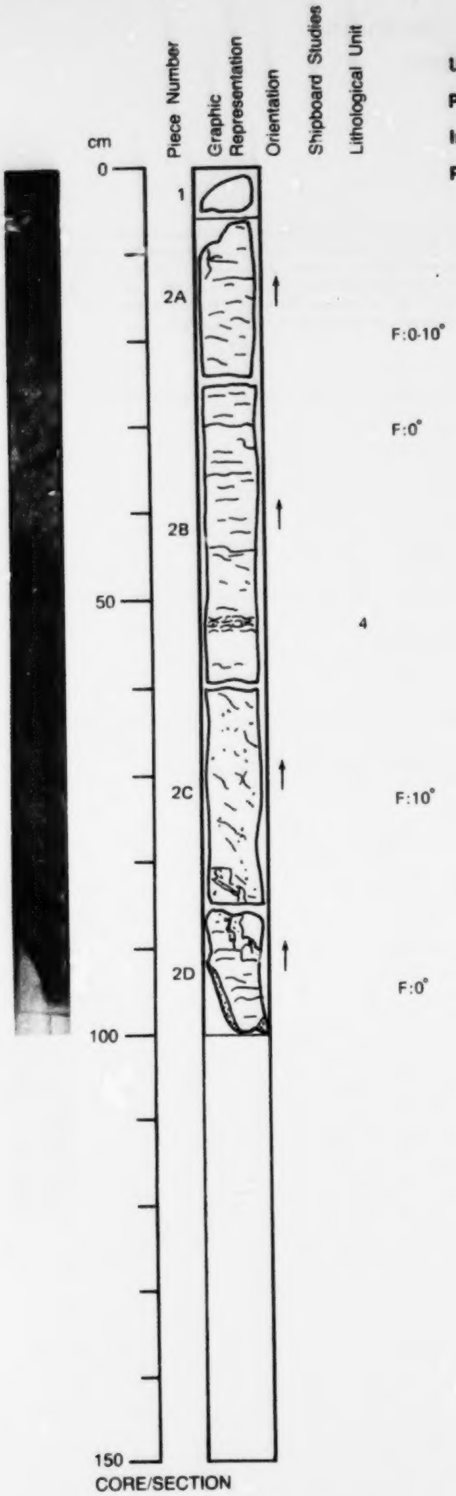
**Iron-Titanium Oxide Gabbro**

**Pieces 1A-1F**

**COLOR:** Gray.
**LAYERING:** None clearly defined. Most of core is medium-grained; a coarse-grained section at 0-10 cm; fine-grained patches at 15-25, 80-90, 110-125, and 135-145 cm. Transitions are not as sharply defined as in some other sections. Olivine, if present, occurs only in trace amounts.
**DEFORMATION:** None apparent; some intervals show a very weakly defined lamination (especially Pieces 1E and 1F), which may in part be igneous. There are a few brittle fractures—subhorizontal. Some larger plagioclases are cut by small vertical fractures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: 1-10 mm.
Crystal shape: Euhedral to anhedral, smaller ones. Those partially enclosed by clinopyroxene are euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1-20 mm.
Crystal shape: Subhedral, anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 5%-20%, a bit less abundant than some shallower sections.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Minor.
Texture: Probably some amphibole after clinopyroxene. Disseminated (< 1 mm) pyrite common throughout.
Percent vein material: One subhorizontal vein in Piece 1F.
Vein material: Not determined.



**118-735B-52R-2**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1-2D

### Iron-Titanium Oxide-Bearing Gabbro

### Pieces 1-2D

**COLOR:** Dark gray.
**LAYERING:** None apparent.
**DEFORMATION:** Foliation is clearly visible throughout the section. The plagioclase is granular, and pyroxene has a preferred orientation. This foliation is probably a secondary feature overprinting a primary foliation (magnetite) that is evident from the sawn surface.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not visible.
Percent replacement: Slight.

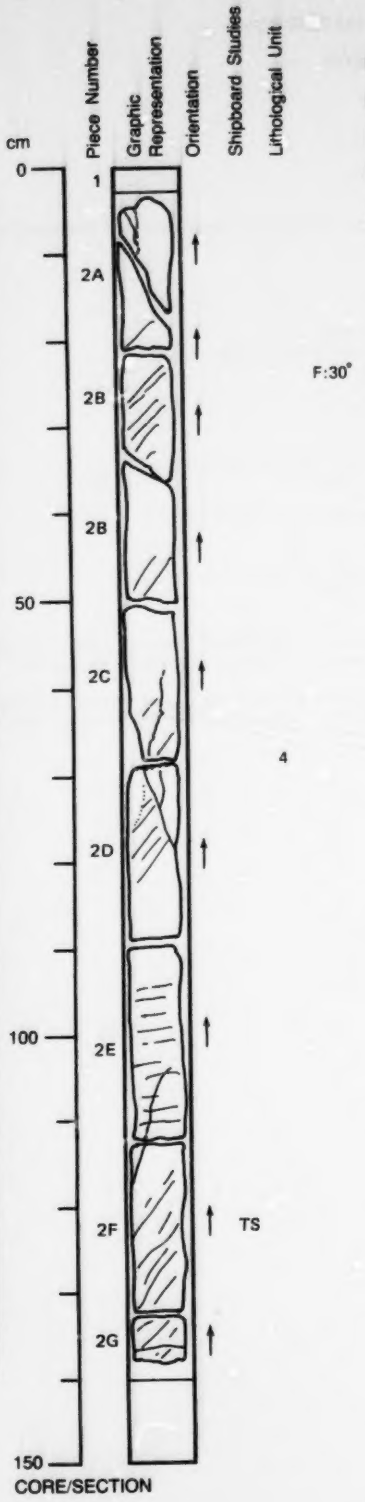
Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-10 mm.
Crystal shape: Lensoid.
Preferred orientation: Strong.
Percent replacement: Moderate to extensive.

Olivine—Mode: Traces (Pieces 1C and 1D).
Crystal size: 1-2 mm.
Crystal shape: Rounded.
Preferred orientation: Not observed.
Percent replacement: Extensive.

Iron-titanium oxides, magnetite, and ilmenite—Mode: 5%-10% (secondary in part).
Crystal size: 1-4 mm.
Crystal shape: Granular.
Preferred orientation: Not determined.
Percent replacement: Extensive.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine replaced by chlorite and magnetite. Plagioclase recrystallized into granoblasts during deformation and partly chloritized and veined by amphibole. Sulfides are disseminated in four parts of Piece 2 (not seen in Piece 1). In Pieces 2C and 2D, sulfides are "concentrated" in or close to a plagioclase-amphibole vein (1 cm thick).
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole. Pieces 2A and 2B: plagioclase veinlets <1 mm across.



118-735B-52R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-2G**

**Iron-Titanium Oxide-Bearing Gabbro**

**Pieces 1-2G**

**COLOR:** Gray.

**LAYERING:** Obscured by deformation.

**DEFORMATION:** Foliation variable. Pieces 2A-D (4-82 cm) dip approximately 30°. At 82-96 cm, obvious foliation disappears. At 96-110 cm, foliation reappears but is more poorly defined and horizontal. Grain size diminishes and/or deformation increases to bottom, where Piece 2G is fine-grained. Foliation defined by preferred orientation of clinopyroxene.

Clinopyroxene has a rounded appearance, not sheared. Plagioclase appears to be granulated or recrystallized.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%.
Crystal size: 0.5-3 cm.
Crystal shape: Anhedral to subhedral where included in clinopyroxene.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Slight to moderate.

Clinopyroxene—Mode: 60%-55%.
Crystal size: 0.5-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Slight to moderate.

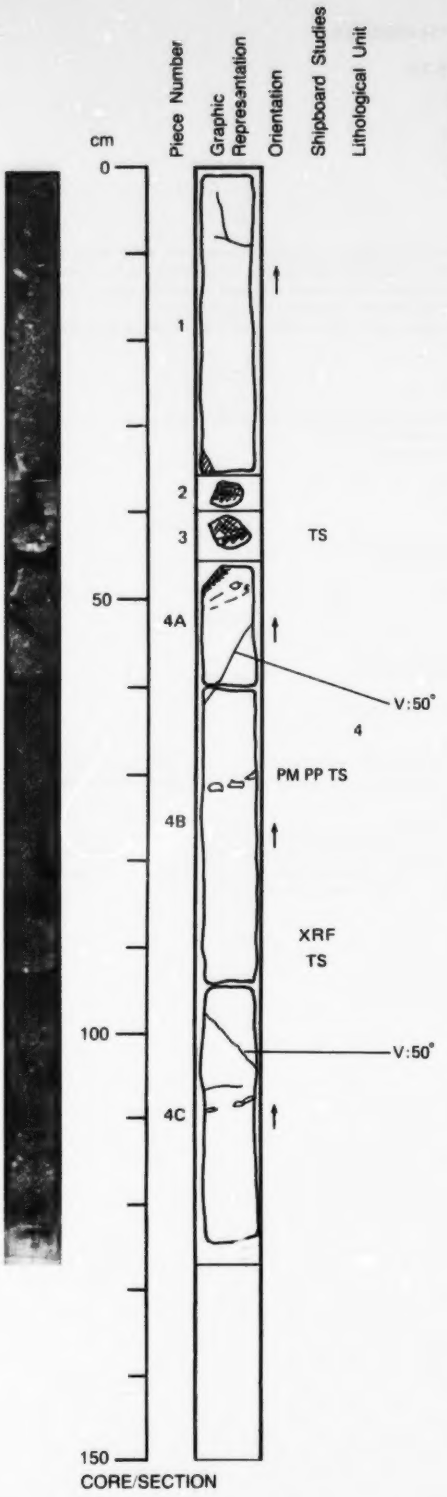
Olivine—Mode: 0%-1%, traces in Pieces 2C-2F.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive.

Iron-titanium oxides—Mode: 5% (primary?).

**SECONDARY MINERALOGY:**

Total percent: Slight to moderate.
Texture: Clinopyroxene partially replaced by amphibole, >10%-15%. Plagioclase recrystallized and partially replaced by greenish mineral. Concentrations of iron-titanium oxides and sulfides throughout the section.
Percent vein material: Not determined.
Vein material: Sodic plagioclase, green amphibole along very thin fractures.

**COMMENTS:** Occasional ophitic texture between plagioclase and clinopyroxene; grain size is variable, clinopyroxene 0.5-1 cm between 0-71 cm. Coarser texture 1-3 cm, at 72-94 cm. Medium-grained at 97-130 cm and fine-grained (<1 mm) at bottom (Piece 2G).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4A
4B
4C
TS
PM PP TS
XRF
TS
V:50°
V:50°
4
CORE/SECTION

**118-735B-52R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-4C**

### Iron-Titanium Oxide-Rich Gabbro

**Pieces 1-4C**

**COLOR:** Gray and black.

**LAYERING:** Grain size and compositional layering—faint, subhorizontal, and paralleled by a poorly developed magmatic foliation.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: <20 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Locally marks faint magmatic foliation.
Percent replacement: Not determined.

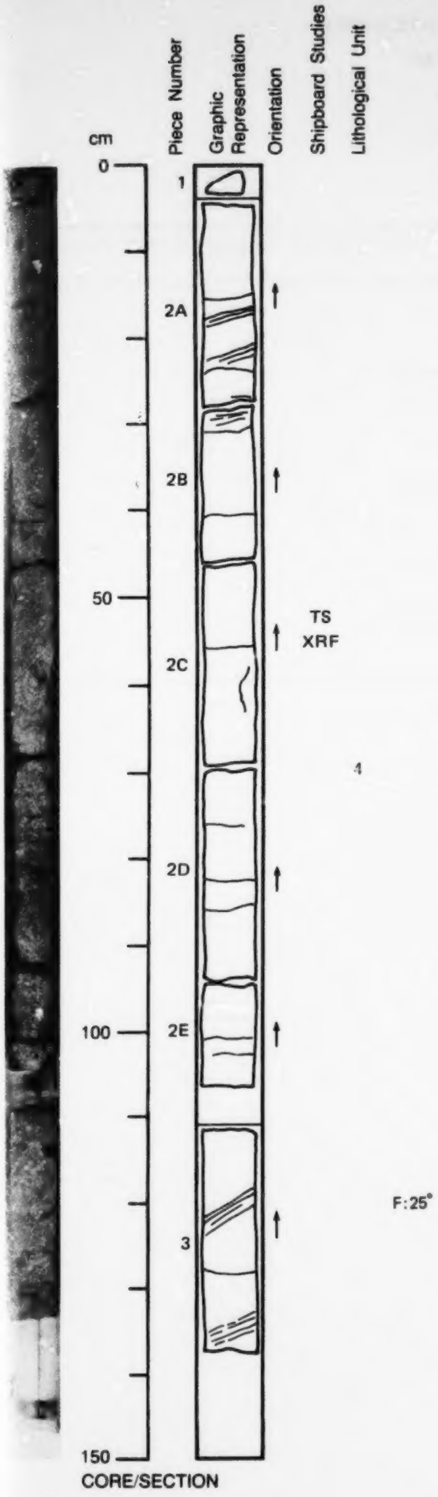
Clinopyroxene—Mode: 30%-40%.
Crystal size: <20 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally marks faint magmatic foliation.
Percent replacement: Not determined.

Olivine—Mode: <5%, not more than 10% in discrete layers.
Crystal size: <20 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally marks faint magmatic foliation.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <30%.
Texture: Pseudomorphic. Replacement of some clinopyroxene by amphibole through the core.
Pieces 2 and 3: Albitization of plagioclase and amphibolitization of clinopyroxene.
Percent vein material: <1%.
Vein material: Green amphibole and sodic plagioclase + green amphibole in Pieces 1, 2, and 3; the veins are not sheared and dip 50°. The veins of sodic plagioclase and amphibole are probably an altered silicic intrusion.

**COMMENTS:** Iron-titanium oxide: primary or secondary?


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2A
2B
2C
2D
2E
3
TS
XRF
4
F:25°
CORE/SECTION

## 118-735B-53R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-3**

**Massive Iron-Titanium Oxide Gabbro**

**Pieces 1-3**

**COLOR:** Medium gray.

**LAYERING:** Weak primary layering defined by slightly alternating grain sizes and enrichment bands of iron-titanium oxides (marked in graphic representation). Inclination 20°-25°. Average grain-size variation from >1 to <0.5 cm.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%.
Crystal size: <0.5 to 2.0 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: <0.5 to 1.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

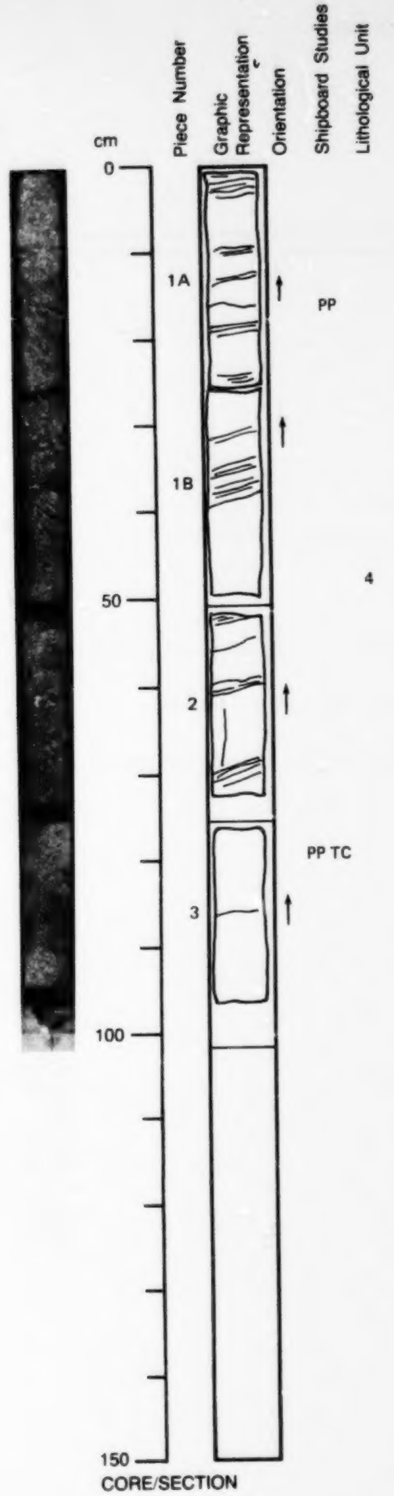
Olivine—Mode: <1% (few grains).
Crystal size: <1.0 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 10% (estimated average, variation between <5% and >30%).

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Green amphibole replaces primary phases along grain boundaries.
Percent vein material: Few veinlets.
Vein material: Not determined.

**COMMENTS:** Iron-titanium oxides enriched throughout section (highly enriched in bands up to 3 cm across).


cm
0
50
100
150
CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1A
1B
2
3
PP
PP TC
4

**118-735B-53R-2**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-3**

**Massive Iron-Titanium Oxide Gabbro**

**Pieces 1A-3**

**COLOR:** Medium gray.

**LAYERING:** Weak primary layering defined by alternating grain sizes and iron-titanium oxide enrichment bands (marked ///). Inclination, <5°-25°. Average grain size varies from 1.5 to <0.5 cm; mostly medium-grained.

**DEFORMATION:** There may be a faint deformation of some small intervals (e.g., 70-75 cm), in general, nonapparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-60%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: <0.5 to 2 cm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by green amphibole.

Olivine—Mode: <2%.
Crystal size: <1.0 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Green amphibole replaces clinopyroxene along grain boundaries; also occurs in veinlets. Few sulfides.
Percent vein material: Not determined.
Vein material: Green amphibole.

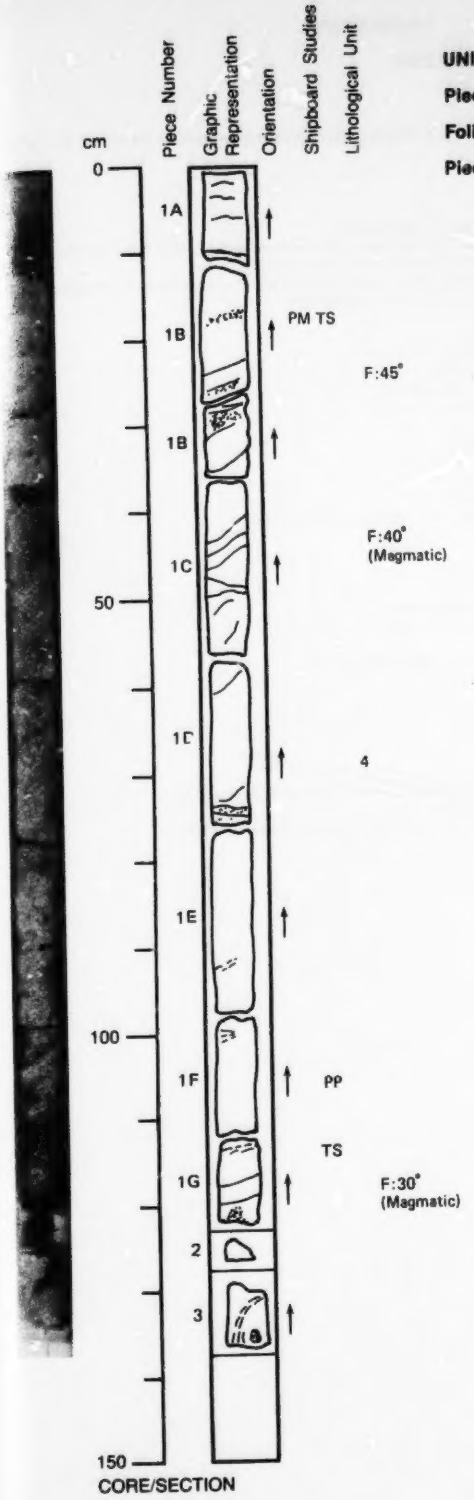
## 118-735B-53R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-3**

### Foliated Iron-Titanium Oxide Gabbro (Microgabbro)

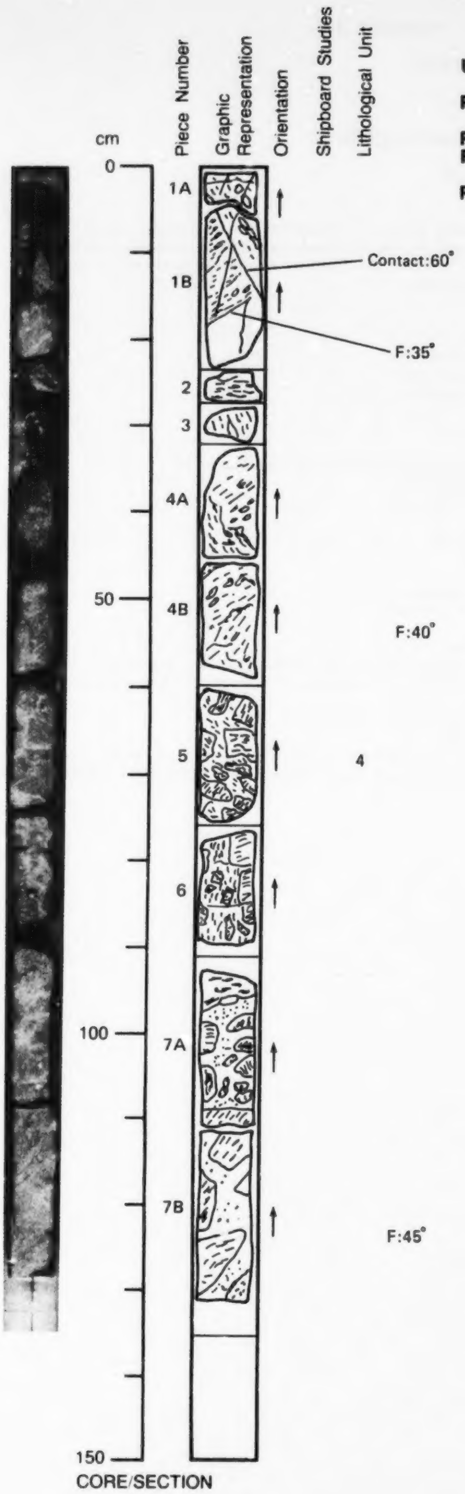
**Pieces 1A-3**


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1A
1B
1B
1C
1D
1E
1F
1G
2
3
PM TS
PP
TS
F:45°
F:40°
(Magmatic)
4
F:30°
(Magmatic)

**COLOR:** Greenish-gray.
**LAYERING:** Possible igneous lamination but hard to differentiate from metamorphic foliation.
**DEFORMATION:** Strong foliation defined by elongated plagioclase and clinopyroxene. Localized mylonitic zones (especially Piece 1A). Zones of cross foliation (especially Piece 1C); Pieces 1E (bottom), 1F, and 1G-3 are gneissic.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 3 mm average.
Crystal shape: Anhedral, filamentous.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 2 mm average.
Crystal shape: Fine-grained anhedral aggregates fill interstitial areas.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 10%.
Crystal size: 2 mm average.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pyroxenes and plagioclase recrystallized. Pyroxenes partly replaced by green amphibole. Black chloritic (?) clay in 1-mm spaces in Pieces 1B-1E (possible replacement of olivine or clinopyroxene).
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Oxide-rich zone in Piece 3. Plagioclase-rich zones in Pieces 1E, 1F, 1G, and 3. Filamentous clinopyroxene with straight edges may have grown under stress in crystal mush.


Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
cm
0
50
100
150
1A
1B
2
3
4A
4B
5
6
7A
7B
Contact:60°
F:35°
F:40°
4
F:45°
CORE/SECTION

**118-735B-53R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-7B

### Foliated, Iron-Titanium Oxide-Bearing Metagabbro (Porphyroclastic) Intruded by Felsic Fine-Grained Rock

### Pieces 1A-7B

**COLOR:** Gray with black streak, locally greenish gray.

**LAYERING:** In Piece 1B, grain size and modal variations show layered structure 2 to 5 cm thick inclining 35°. This 2-cm-thick layer is rich in plagioclase.

**DEFORMATION:** Foliation defined by opaque streaks and stretched clinopyroxene porphyroclasts. The foliation is parallel to the layering and inclines 40°.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: None.

Clinopyroxene—Mode: 30%.
Crystal size: 1-5 mm.
Crystal shape: Subhedral.
Preferred orientation: Marked.
Percent replacement: Extensively replaced by amphibole.

Olivine—Mode: <3%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Opaque mineral, iron-titanium oxide—Mode: 10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Marked.
Percent replacement: None.

**SECONDARY MINERALOGY:**

Total percenet: Extensive.
Texture: Clinopyroxene is replaced by amphibole in Pieces 1A and 1B.
Percent vein material: Moderate.
Vein material: Amphibole. <0.5-mm-thick veins occur that incline 30°.

## 118-735B-53R-4 (continued)

### Felsic Intrusion (Trondhjemite)

### Pieces 1A-7B

**COLOR:** White, light gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 75%.
Crystal size: 0.2-1 mm.
Crystal shape: Euhedral.
Preferred orientation: Marked.
Percent replacement: None.

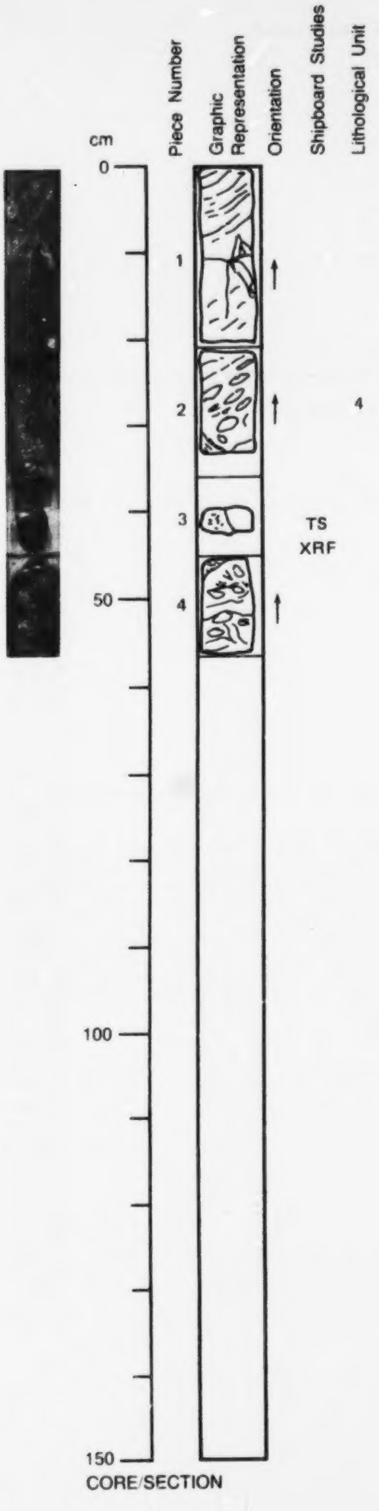
Clinopyroxene—Mode: 4%.
Crystal size: 0.2-1 mm.
Crystal shape: Euhedral.
Preferred orientation: Marked parallel to the contact with the surrounding gabbro (Pieces 1A, 5, and 6).
Percent replacement: 50% replaced by amphibole.

Quartz—Mode: 20%.
Crystal size: 0.2-1 mm.
Crystal shape: Not determined.
Preferred orientation: Not clear.
Percent replacement: None.

Biotite—Mode: 3%-2%.
Crystal size: 0.2-1 mm.
Crystal shape: Euhedral, oikocrystic.
Preferred orientation: Marked.
Percent replacment: None.

Opaque—Mode: 2%.
Crystal size: 0.1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: None.
**SECONDARY MINERALOGY:**
Total percent: <2%.
Texture: Clinopyroxene is replaced from the margin by dark green mineral (amphibole?).
Percent vein material: None.
Vein material: None.

**COMMENTS:** Felsic rocks show wide modal variation. In Pieces 5 and 6, where contacts with gabbro are very sharp, these rocks are richer in plagioclase than in Pieces 1A and 1B, which are richer in clinopyroxene. In Pieces 5 and 6, clinopyroxene is present up to 3%. In Pieces 1A and 1B, felsic rock contains foliated opaque-rich gabbro fragments that seem to be in the process of "digestion." This is probably also the case in Pieces 7A and 7B. In Pieces 4A and 4B, where opaque-rich and opaque-poor portions occur with fairly sharp contact, the foliation in opaque-rich portion abruptly disappears at the contact. The opaque-rich portion is foliated opaque-bearing gabbro, and the opaque-poor portion is probably a mixture of small gabbro fragments and felsic intrusions. In Pieces 5 and 6, foliations of each gabbro fragment show various attitudes, suggesting rotation in felsic magma.



118-735B-53R-5

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-4**

### Foliated Iron-Titanium Oxide Gabbro

**Piece 1**

**COLOR:** Gray to white-gray.
**LAYERING:** None. Fine-grained rock.
**DEFORMATION:** Foliation defined by stretching of plagioclase and clinopyroxene. Upper half has a gneissic appearance due to leucocratic bands (~2 mm across).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Not determined.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: Not determined.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <20% by amphibole.

Olivine—Mode: Some.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 5%.
**SECONDARY MINERALOGY:**
Total percent: Up to 20%.
Texture: Green amphibole replacing clinopyroxene.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Leucocratic bands: either due to albitization or "lit par lit" intrusion of felsic melt (trondhjemitic?).

### Porphyroclastic Iron-Titanium Oxide Gabbro

**Pieces 2, 3 (right half), and 4**

**COLOR:** Gray (variable from dark gray to greenish-whitish gray).
**LAYERING:** None.
**DEFORMATION:** Defined by stretching of clinopyroxene and plagioclase, and development of porphyroclastic structures. Grain size: Coarse-grained (1-2 cm) to medium-grained (0.5-1.0 cm).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Albitization.

Clinopyroxene—Mode: 35%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <15% by green amphibole.

Olivine—Mode: <2%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 10%.
**SECONDARY MINERALOGY:**
Total percent: Up to 10% or more.
Texture: Green amphibole replacement of clinopyroxene. Albitization of plagioclase. Sulfides.
Percent vein material: Not determined.
Vein material: Not determined.

### 118-735B-53R-5 (continued)

**Fine-Grained Felsic Dike (Trondhjemite)**

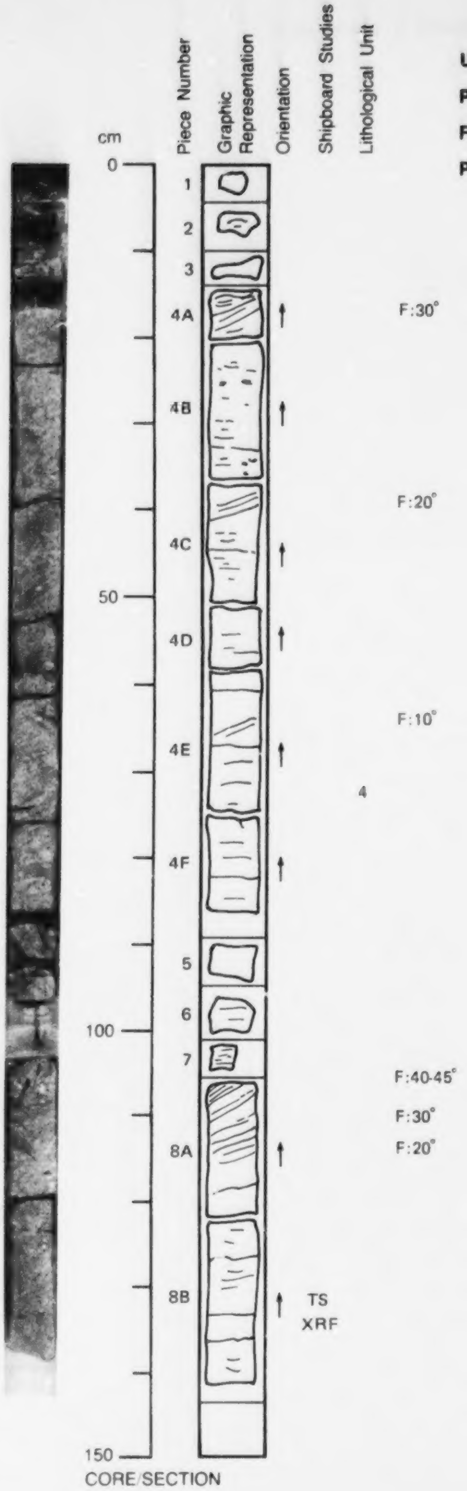
**Piece 3 (left half)**

**COLOR:** Grayish-white.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 70%.
  Crystal size: 0.1-1.0 mm.
  Crystal shape: Subhedral.
  Preferred orientation: Not determined.
  Percent replacement: Not determined.

- Quartz—Mode: 20%-25%.
  Crystal size: 0.3-1.0 mm.
  Crystal shape: Anhedral.
  Preferred orientation: Not determined.
  Percent replacement: Not determined.

- Biotite—Mode: 3%-5%.
  Crystal size: 0.1-2.0 mm.
  Crystal shape: Subhedral.
  Preferred orientation: Not determined.
  Percent replacement: Not determined.

**SECONDARY MINERALOGY:** Not determined.
**COMMENTS:** >95% felsic minerals (plagioclase and quartz), some biotite.



## 118-735B-54R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-8B**

**Foliated Iron-Titanium Oxide Gabbro (Olivine-Bearing)**

**Pieces 1-8B**

**COLOR:** Gray, with yellowish-olive speckles.

**LAYERING:** None apparent. On average, medium-grained, some coarser-grained (1.0-2.0 cm) intervals.

**DEFORMATION:** Defined by stretching of clinopyroxene, plagioclase, and olivine. Intensity varies over length of section. There are zones of intense foliation (Pieces 4A (top), 4C, 4E, 5, and 8A) alternating with zones of weak to very weak foliation. Pieces 6, 7, and the very top of 8A are mylonitized.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: < 10% by amphibole.

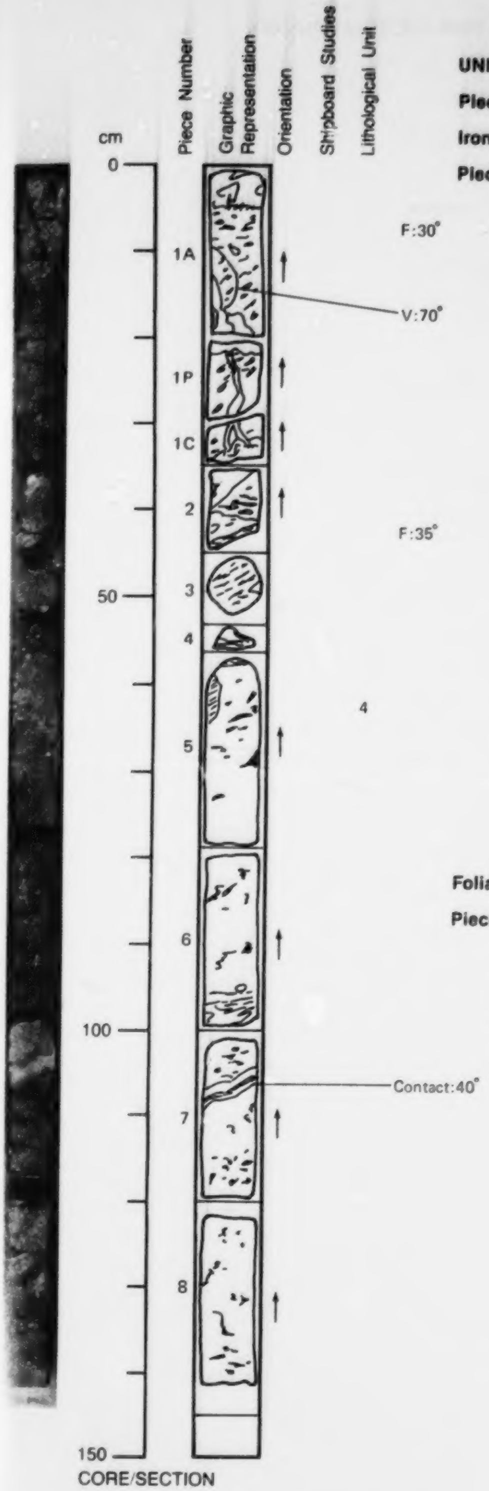
Olivine—Mode: <5%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Partially replaced.

**SECONDARY MINERALOGY:**

Total percent: < 10%.
Texture: Amphibole partially replaces clinopyroxene. Olivine partially replaced, alteration products could not be determined macroscopically, some black pseudomorphs. Sulfide dissemination—pyrite(?).
Percent vein material: Few veins and veinlets.
Vein material: Mostly filled with white minerals (albite?), especially Pieces 1, 2, 3, and 4A.

**COMMENTS:** Rock contains considerable amounts of iron-titanium oxides, precise proportion difficult to estimate. 2%-10% iron-titanium oxides (5% on average), occurring in layers and small bands. Olivine content varies over length of section from about 2% in upper third to about 10% in Pieces 8A and 8B. Average content is 5%.

118-735B-54R-2



## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-8

### Iron-Titanium Oxide-Bearing Olivine Gabbro

### Pieces 1A (bottom)-1C (top), 3, 5 (bottom)-8

**COLOR:** Gray, olive-speckled.
**LAYERING:** None apparent.
**DEFORMATION:** Foliation defined by opaque streaks and elongated clinopyroxene and olivine grains in Pieces 1A, 1B, 2-5, 6 (top), and 7. Pieces 3 and 4 are typically prophyroclastic with mylonitic bands. The foliation is sharply cut by later felsic intrusion in Pieces 1A and 7.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral.
Preferred orientation: Marked.
Percent replacement: None apparent.

Clinopyroxene—Mode: 15%-25%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Marked.
Percent replacement: < 10% by amphibole.

Olivine—Mode: 10%-25%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Marked.
Percent replacement: Locally replaced by talc and tremolite or oxidized.

Iron-titanium oxide—Mode: 5%-10%.
Crystal size: Aggregates 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Marked.
Percent replacement: None.
**SECONDARY MINERALOGY:**
Total percent: < 7%.
Texture: Amphibole after clinopyroxene less than 5%. Olivine is locally altered into chlorite? and oxidized in Pieces 4 and 5. Olivine fragments in felsic rock are altered into talc and tremolite.
Percent vein material: Not determined.
Vein material: Not determined.

### Foliated Microgabbro

### Pieces 4 and 5 (top)

**COLOR:** Greenish-gray.
**LAYERING:** Not determined.
**DEFORMATION:** Well-foliated; Foliation is parallel to the surrounding mylonitic one.
**PRIMARY MINERALOGY:** Primary mineralogy cannot be determined.
**SECONDARY MINERALOGY:** Not determined.
**COMMENTS:** 0.5 mm grainsize. Rich in amphibole (30%).

**118-735B-54R-2 (continued)**

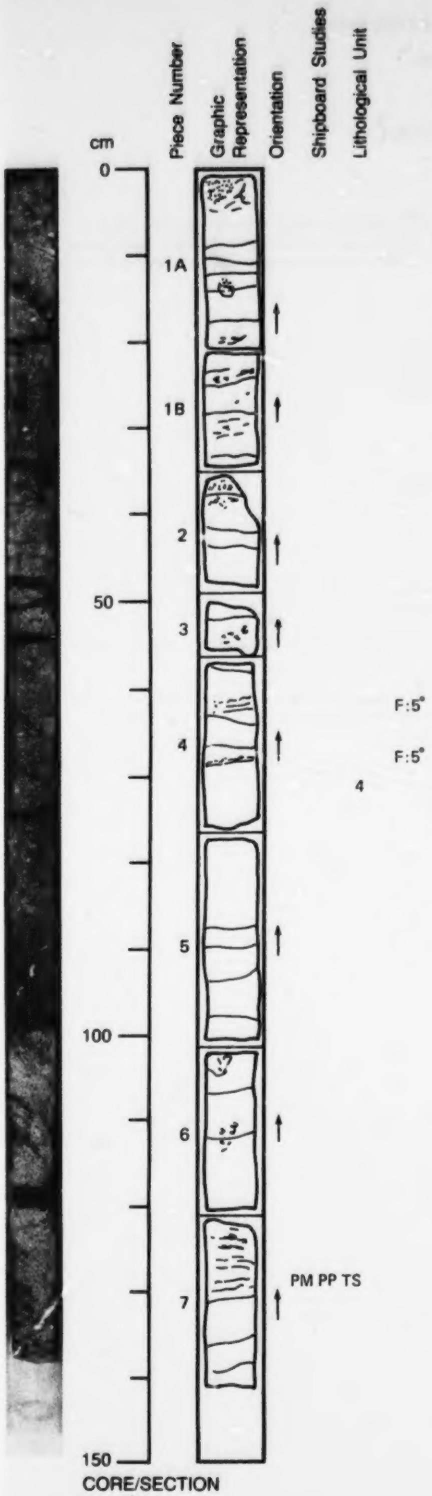
## Felsic Rock

### Pieces 1A (top), 1C (bottom), 2, and 7.

**COLOR:** Light gray-white.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
  Plagioclase—Mode: Not determined.
  Crystal size: 0.5-1 mm.
  Crystal shape: Euhedral.
  Preferred orientation: Not clear.
  Percent replacement: None.

  Clinopyroxene—Mode: 3%.
  Crystal size: 0.1 mm.
  Crystal shape: Euhedral.
  Preferred orientation: Not clear.
  Percent replacement: Not determined.

  Magnetite—Mode: 2%.
  Crystal size: 0.5 mm.
  Crystal shape: Euhedral.
  Preferred orientation: Not clear.
  Percent replacement: None.
**SECONDARY MINERALOGY:** Almost none.
**COMMENTS:** Quartz mode not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3
4
5
6
7
F:5°
F:5°
4
PM PP TS
CORE/SECTION

## 118-735B-54R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-7**

## Massive Iron-Titanium Oxide-Bearing Olivine Gabbro

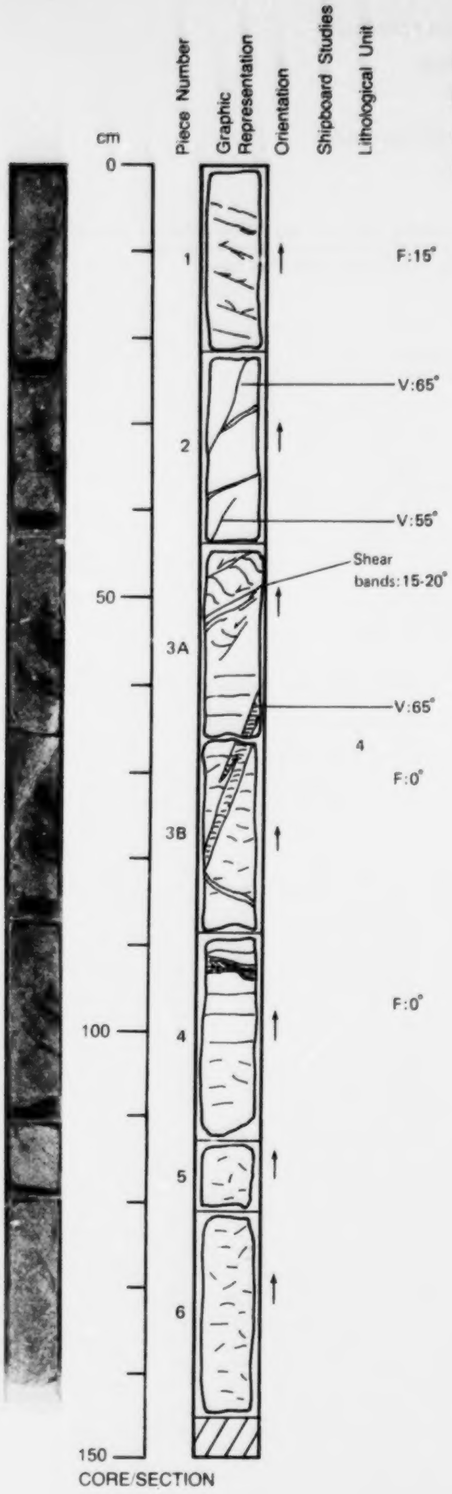
**Pieces 1A-7**

**COLOR:** Medium gray.
**LAYERING:** Weak primary layering; indicated by slight grain size variations: Pieces 1, 2 (upper half), 3, and top of 7 are coarse-grained (1-2 cm); the remainder is medium-grained.
**DEFORMATION:** Very weak, if any. Slight foliation to be observed in Piece 4.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: <2%-8%, (5% on average).
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: <1%-5%, (3% on average).
**SECONDARY MINERALOGY:**
Total percent: <15%.
Texture: Amphibole replacement, especially along grain boundaries. Olivine in parts fresh.
Pyrite.
Percent vein material: Few veins and veinlets with white mineral(s).
Vein material: Not determined.
**COMMENTS:** Iron-titanium oxide enrichment indicated by stippled zones.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3A
3B
4
5
6
F:15°
V:65°
V:55°
Shear bands: 15-20°
V:65°
4
F:0°
F:0°
CORE/SECTION

**118-735B-54R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1-6

### Olivine Gabbro Rich in Iron-Titanium Oxides

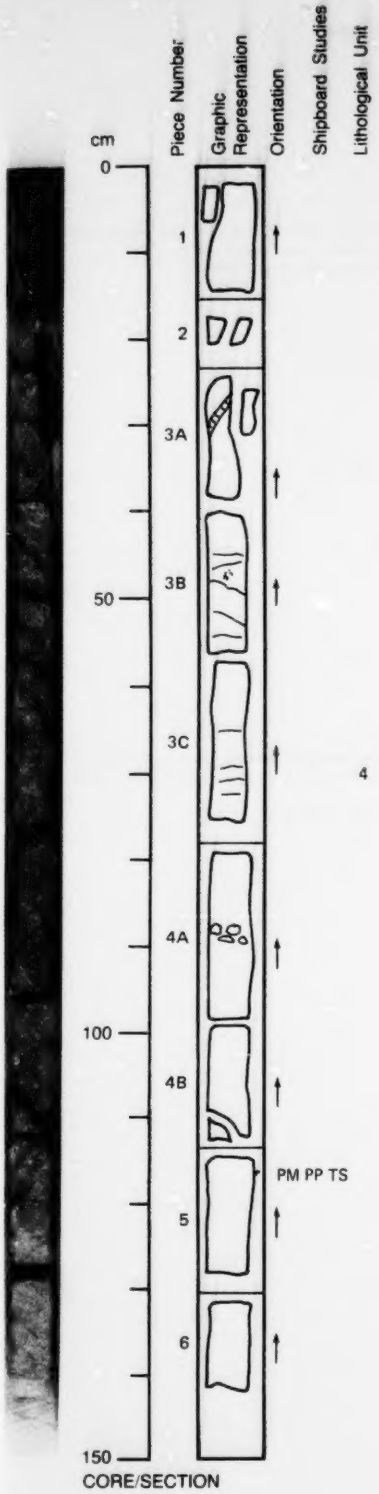
### Pieces 1-6

**COLOR:** Gray-green.
**LAYERING:** Faint grain-size layering in Piece 1. Magmatic foliation in Pieces 1, 3B, and 4.
**DEFORMATION:** A zone of deformation in Pieces 2 and 3. The plastic foliation is deformed by discrete shear zones with a normal offset. The iron-titanium oxides tend to concentrate in these shear bands.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Medium to coarse.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Marks foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: Medium to coarse.
Crystal shape: Anhedral.
Preferred orientation: Marks foliation.
Percent replacement: Not determined.

Olivine—Mode: 10%-15%.
Crystal size: Medium to coarse.
Crystal shape: Anhedral.
Preferred orientation: Marks foliation.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: Up to 10%-20% in enriched zones: late primary or secondary?
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene amphibolitized (green amphibole) and plagioclase albitized, especially in Piece 2. Alteration of a certain amount of clinopyroxene to brown amphibole?
Percent vein material: Not determined.
Vein material: Not determined.



**118-735B-54R-5**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-6**

**Iron-Titanium Oxide Gabbro**

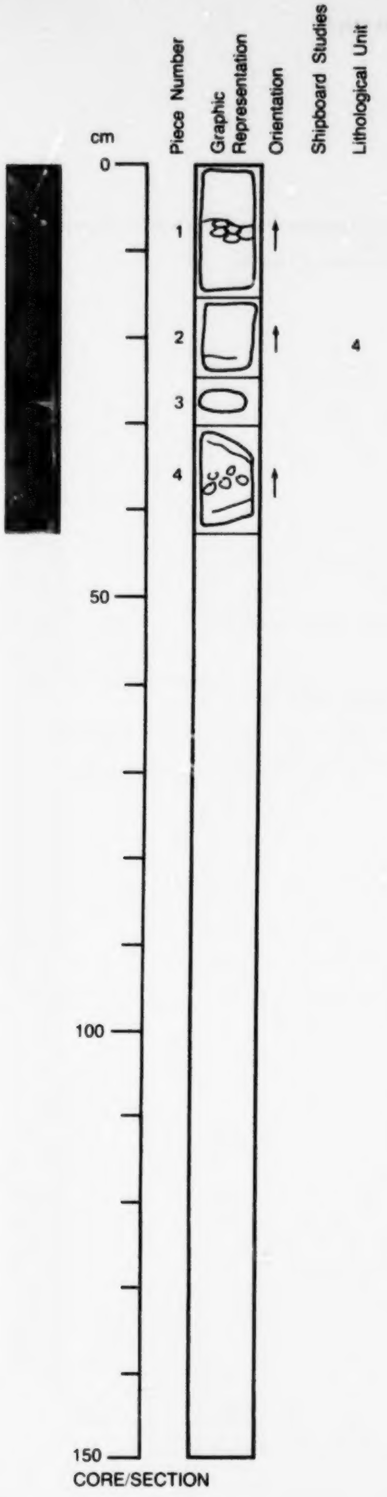
**Pieces 1-6**

**COLOR:** Gray.
**LAYERING:** Igneous lamination defined by elongated plagioclase and clinopyroxene is subhorizontal in most places, but dips up to 30° in Piece 2C.
**DEFORMATION:** Weak foliation, best developed in middle of Piece 3B.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-45%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 3-8 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxide—Mode: 10%-20%, fine-grained aggregates.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Black chloritic clay (?) or magnetite (?) replacing olivine. Green amphibole replacing clinopyroxene, but not as extensively as some nearby sections.
Percent vein material: Not determined.
Vein material: White (0.5-1 mm) veins are subhorizontal. Plagioclase-amphibole vein in Piece 3A.
**COMMENTS:** Fresh olivine intergrown with primary iron-titanium oxide. Coarse-grained, pyroxene-rich interval in the middle of Piece 4A.



**118-735B-54R-6**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-4**

**Iron-Titanium Oxide Gabbro**

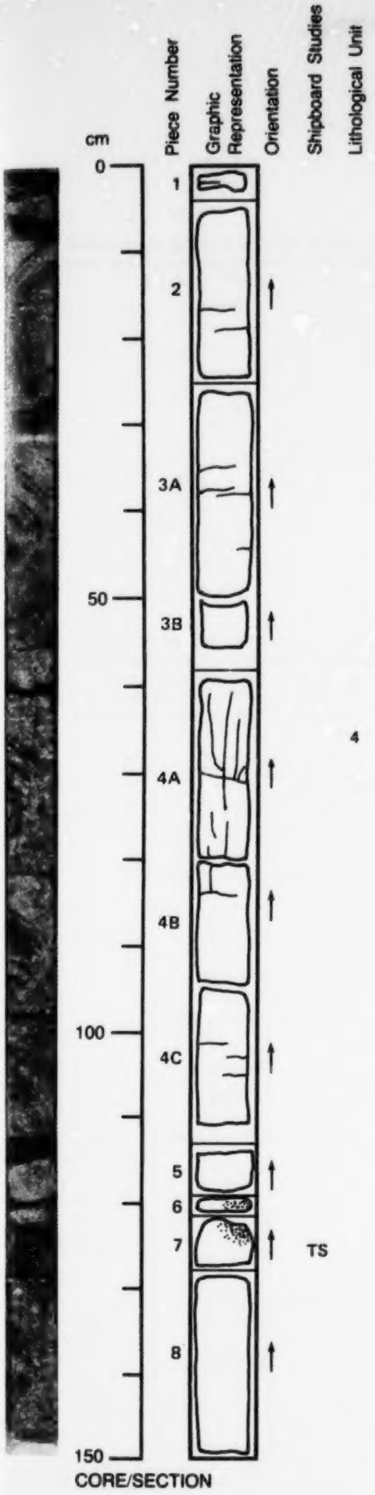
**Pieces 1-4**

**COLOR:** Gray.
**LAYERING:** Primary layering defined by variation in grain-size from coarse to very coarse in Pieces 1 and 4 and by preferred orientation of clinopyroxene in Pieces 1 and 2.
**DEFORMATION:** Very weak foliation (?) parallel to primary layering in Piece 2.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-45%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Not determined.

Olivine—Mode: 5%.
Crystal size: 3-8 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Fresh.

Ilmenite—Mode: 10%-20%.
Crystal size: Fine-grained aggregates.
Crystal shape: Anhedral, rounded.
Preferred orientation: None.
Percent replacement: 0%.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Green amphibole replacing clinopyroxene at grain boundaries and plagioclase along fractures. Thin, white vein in Piece 1 is nearly horizontal. Trace of sulfides throughout.
Percent vein material: Not determined.
Vein material: White mineral, probably sodic plagioclase.



**118-735B-55R-1**

**UNIT 4: IRON-TITANIUM OXIDE GABBRO**

**Pieces 1-8**

**Iron-Titanium Oxide Gabbro**

**Pieces 1-8**

**COLOR:** Gray.

**LAYERING:** Subtle layering throughout defined by changes in grain size and preferred orientation of pyroxenes.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-45%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 25%-30% albitization.

Clinopyroxene—Mode: 45%.
Crystal size: 3-20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 40%-50% by amphibole.

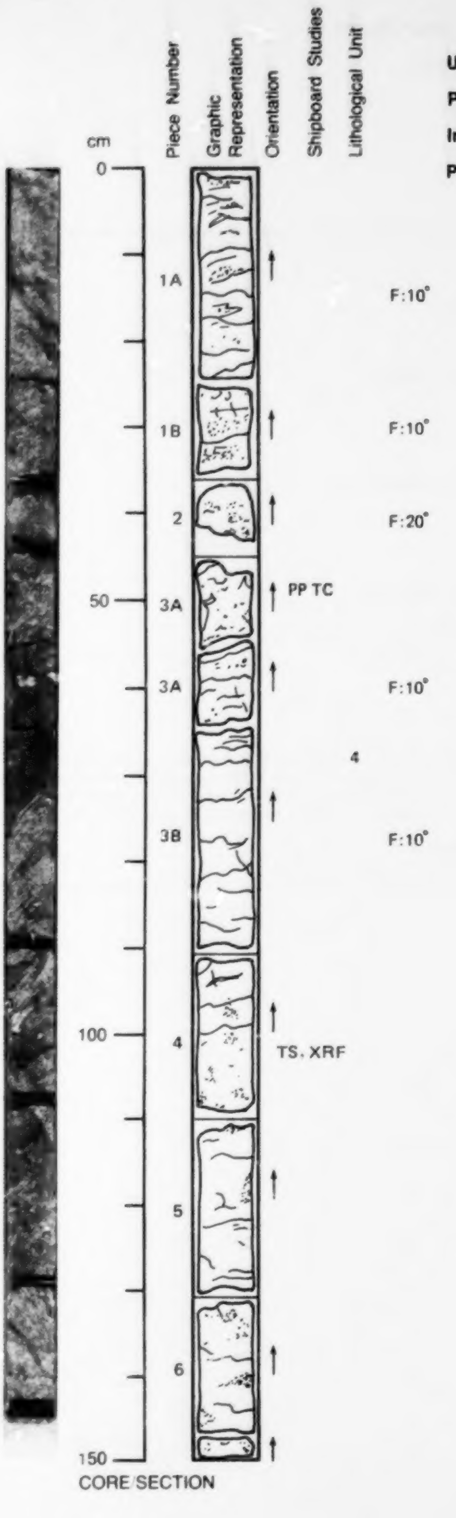
Olivine—Mode: 0%-5%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% by amphibole.

Iron-titanium oxides—Mode: 10%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: None.
Percent replacement: 0%.

**SECONDARY MINERALOGY:**

Total percent: 20%-30%.
Texture: Clinopyroxene replaced partially by amphibole. Alteration most intense in Piece 4A, where plagioclase is milky white and albitized and portions of Pieces 6 and 7, where alteration includes a white fibrous to platy mineral growing into apparently open voids and green minerals, actinolite and chlorite (?). Trace of sulfides throughout. Numerous tiny amphibole veinlets throughout.
Percent vein material: Not determined.
Vein material: Amphibole, chlorite, and a white mineral.

**COMMENTS:** A few euhedral plagioclases enclosed in clinopyroxene, but not strong subophitic texture as seen in earlier cores.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1A
F:10°
1B
F:10°
2
F:20°
50
3A
PP TC
3A
F:10°
4
3B
F:10°
100
4
TS, XRF
5
6
150
CORE SECTION

### 118-735B-55R-2

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1A-6

### Iron-Titanium Oxide-Bearing Olivine Gabbro

### Pieces 1A-6

**COLOR:** Dark gray to gray.

**LAYERING:** None apparent.

**DEFORMATION:** Very weak in Pieces 1A, 1B, 2, 3A, and 3B. Pyroxene is aligned in a preferred orientation, and plagioclase has a granular surface. This deformation is in part primary.

**PRIMARY MINERALOGY:**

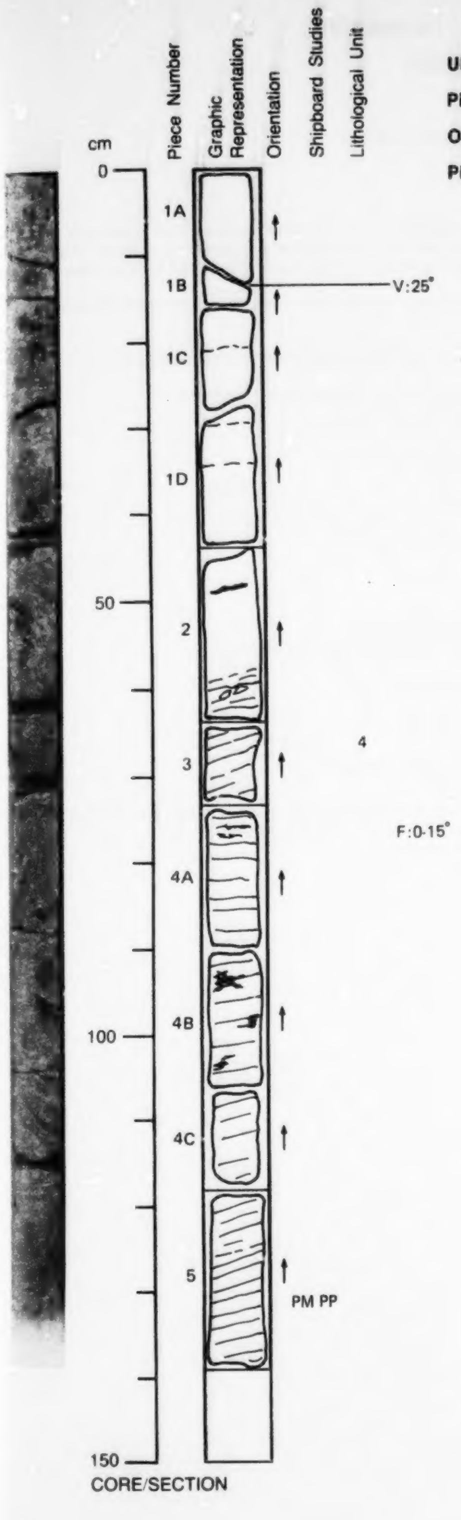
Plagioclase—Mode: 50%-60%.
Crystal size: 1-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not visible.
Percent replacement: None.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Weak but measurable.
Percent replacement: Slight to moderate.

Olivine—Mode: 1%-2%.
Crystal size: 1-3 mm.
Crystal shape: Rounded.
Preferred orientation: Not visible.
Percent replacement: Severely.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine replaced by black chlorite and orangish brown iron hydroxides. Clinopyroxene partly replaced by amphiboles. Cracks and veinlets filled by plagioclase (flat cracks) and irregularly oriented veinlets filled with amphibole (in pyroxene, plagioclase, matrix). Sulfides are relatively abundant (up to 1% in Piece 5), mainly pyrite with granular shape, seen in cracks or disseminated in the rock. There are < 1-2 mm thick patches. In Piece 5 sulfides are filling small fractures, cutting amphibole and chlorite.
Percent vein material: Not determined.
Vein material: Not determined.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### 118-735B-55R-3

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-5**

### Olivine and Iron-Titanium Oxide-Bearing Gabbro

**Pieces 1A-5**

**COLOR:** Grayish black.

**LAYERING:** Some grain-size layering, subhorizontal. No magmatic lamination, no compositional layering apparent, except for subhorizontal oxide-rich layers.

**DEFORMATION:** No deformation above 60 cm. Plastic deformation increasing from 60 to 140 cm. Foliation subhorizontal. Texture: poorly foliated to well foliated (porphyroclastic).

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-15 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Marks foliation.
Percent replacement: Some albitization in Piece 1A.

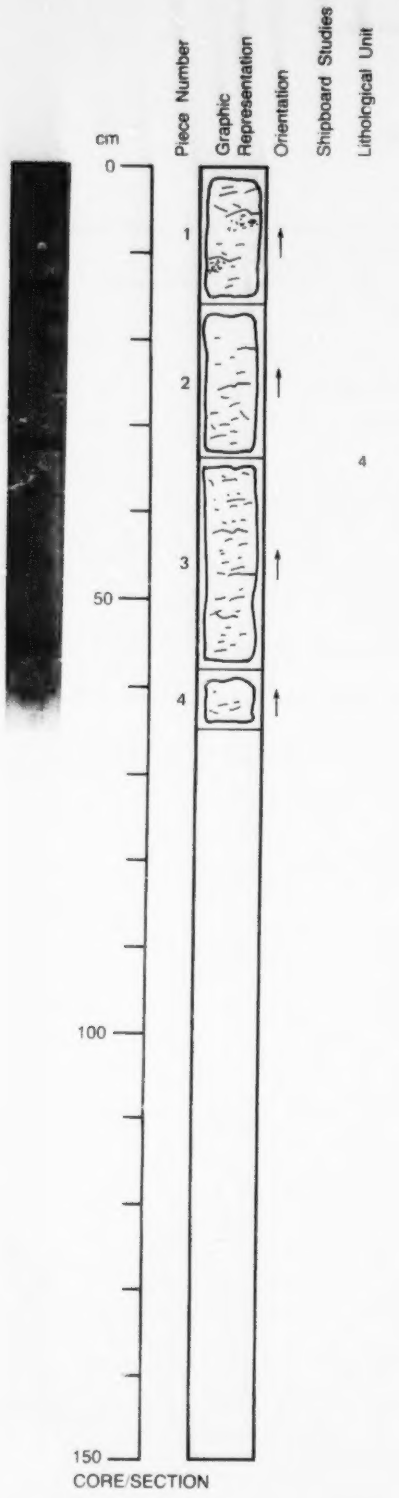
Clinopyroxene—Mode: 35%-40%.
Crystal size: 1-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Marks foliation.
Percent replacement: 30% by amphibole.

Olivine—Mode: <5%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Marks foliation.
Percent replacement: Replaced by amphibole.

Iron-titanium oxides—Mode: Up to 20% in places. Late primary and secondary.

**SECONDARY MINERALOGY:**

Total percent: >30%.
Texture: Pseudomorphic amphibole after clinopyroxene and olivine. Not much albitization of plagioclase, except in Piece 1A.
Percent vein material: <1%.
Vein material: Amphibole and sulfide vein in Piece 1; also very small subhorizontal white veins.



**118-735B-55R-4**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-4**

### Iron-Titanium Oxide and Olivine-Bearing Gabbro

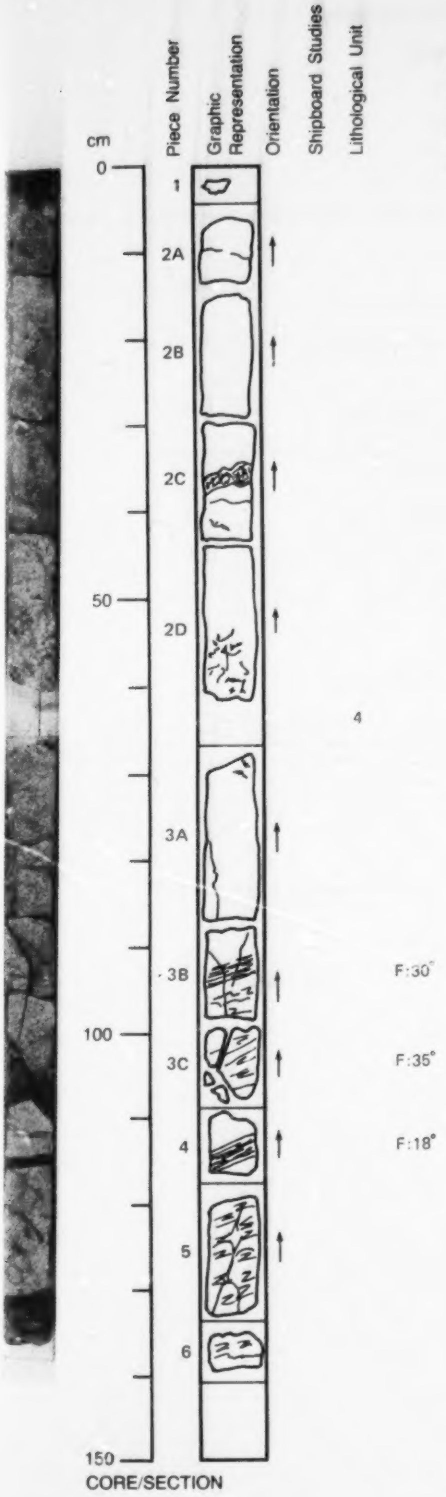
**Pieces 1-4**

**COLOR:** Gray to greenish gray.
**LAYERING:** A distinct lamination to this section. Distinct olivine-rich zones (with grains up to 1 cm) occur at 35 and 58 cm, but olivine occurs throughout—size layering is indistinct; coarse at 65 cm, medium to 36 cm, coarser at 35 cm to mixed fine and medium at 10-15 cm, back to coarse at 0-5 cm.
**DEFORMATION:** A well-developed lamination may be in part deformational. Several subhorizontal brittle fractures cut core.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 30%-70%; some small-scale pyroxene-plagioclase variation.
Crystal size: 1-13 mm.
Crystal shape: Subhedral to anhedral, rarely euhedral in clinopyroxene.
Preferred orientation: Elongate in lamination.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-60%.
Crystal size: 1-12 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Very elongate pyroxene in lamination.
Percent replacement: Up to 30% by amphibole.

Olivine—0%-15% locally.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Elongate in lamination.
Percent replacement: Tremolite/opaque replacements common.

Iron-titanium oxides—Mode: 2%-10%.
Crystal size: <1-4 mm.
Crystal shape: Anhedral, interstitial.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-30%.
Texture: Significant replacement of clinopyroxene by amphibole. Slight greenish cast to a lot of clinopyroxene. Also, a little talc-tremolite after clinopyroxene or olivine.
Percent vein material: Not determined.
Vein material: Not determined.



### 118-735B-56R-1

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1-6**

**Olivine Bearing Iron-Titanium Oxide Gabbro**

**Pieces 1-6**

**COLOR:** Gray; gray to white where veined.

**LAYERING:** Two coarse to fine transitions, one long medium-grained interval. Olivine identified in zones at 8, 30-35, 40-50, 82, 100-105, and 129 cm. A pyroxene-ilmenite-rich band at 37 cm dips into core at about 10°.

**DEFORMATION:** Weak lamination in core, with a rather sharp contact with mylonite zone at 93 cm. There is a lot of brittle fracturing, particularly at 90-140 cm. At 93-95 cm and 114-117 cm there are bands of mylonitized iron-titanium oxide olivine gabbro. There are lenses and grains of gabbro in mylonite. At 95-114 cm and 117-140 cm there are zones of porphyroclastic iron-titanium oxide olivine gabbro.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 20%-60%.
Crystal size: 1-10 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Weak magmatic(?) foliation.
Percent replacement: Not determined

Clinopyroxene—Mode: 40%-60%.
Crystal size: 1-15 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Weak magmatic(?) foliation.
Percent replacement: Extensively altered to amphibole

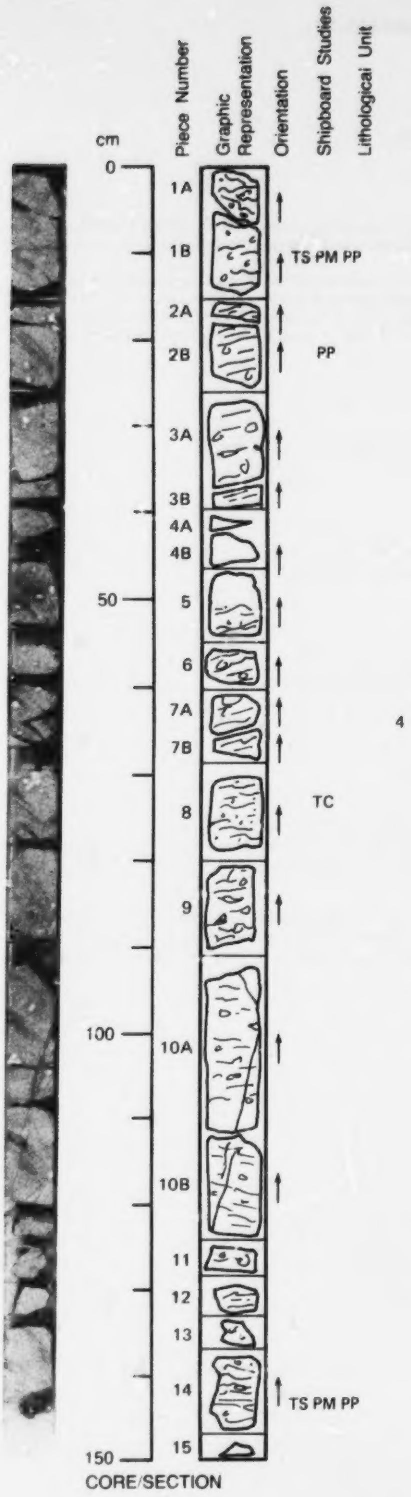
Olivine—Mode: 0%-8%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Commonly altered to talc/tremolite

Iron-titanium oxide—Mode: 2%-15%.
Crystal size: 0.5-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Moderate to extensive (30%?) mostly of ferromagnesians).
Texture: Pyroxene has a very greenish cast—probably altered in large part to fine-grained amphibole. Plagioclase appears fresh. Minor amphibole growth along veins.
Percent vein material: Not determined.
Vein material: Not determined.

**COMMENTS:** A feldspathic zone occurs at 55-60 cm, largely coarse, primary plagioclase surrounded by a network of fine, granular textured, white feldspathic material. Hard to tell if there is any quartz. Could be a late stage magmatic-deuteric vein or a brecciated zone with white granulated plagioclase.



**118-735B-56R-2**

## UNIT 4: IRON-TITANIUM OXIDE GABBRO

**Pieces 1A-15**

### Mylonitized Magnetite-Olivine Gabbro

**Pieces 1A-15**

**COLOR:** Gray.

**LAYERING:** Olivine-rich zones (Piece 3A) suggest an original primary igneous layering, now obscured by deformation.

**DEFORMATION:** Mylonitized and finely laminated.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%(?).
Crystal size: Very fine (<1 mm), except augen.
Crystal shape: Anhedral.
Preferred orientation: Strained and recrystallized grains define lamination.
Percent replacement: Not determined

Clinopyroxene—Mode: 15%(?).
Crystal size: Very fine (<1 mm), except augen.
Crystal shape: Anhedral.
Preferred orientation: Strained and recrystallized grains define lamination.
Percent replacement: Not determined

Olivine—Mode: 0%-7%, estimated.
Crystal size: Very fine (<1 mm), except augen.
Crystal shape: Anhedral.
Preferred orientation: Strained and recrystallized grains define lamination.
Percent replacement: Not determined

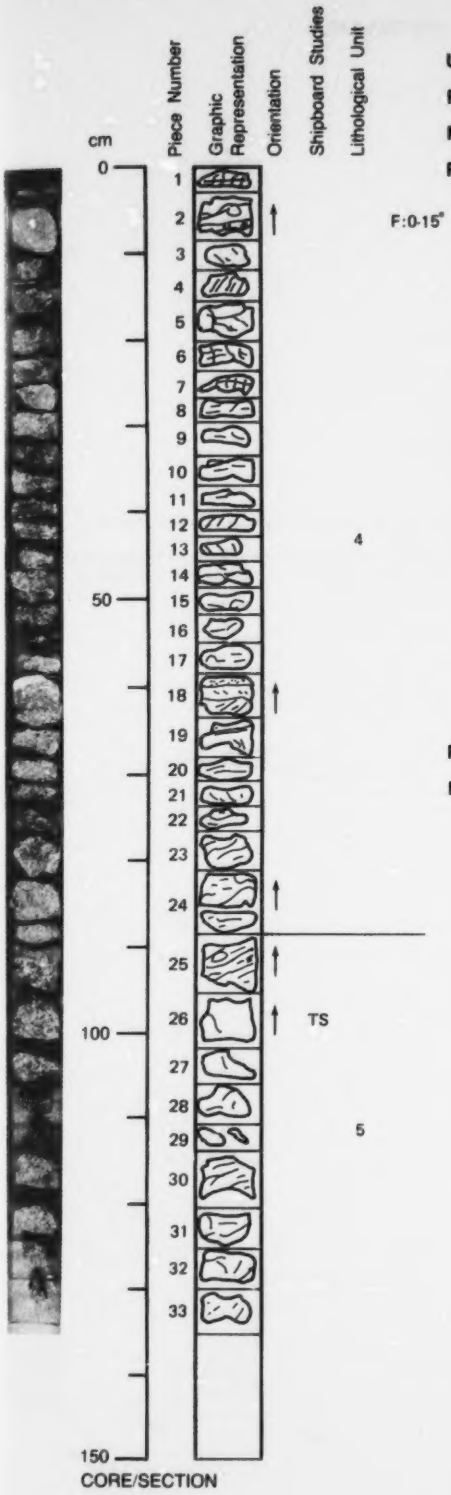
Magnetite/ilmenite—Mode: 10%-13%.
Crystal size: Very fine (<1 mm).
Crystal shape: Anhedral(?).
Preferred orientation: Not determined.
Percent replacement: Not apparent in handspecimen.

**SECONDARY MINERALOGY:**

Total percent: Up to 30% amphibole and chlorite seen locally.
Texture: Very fine grained laminated mylonite with numerous rolled clinopyroxene augen. Olivine-rich zones include coarse augen of olivine with an elongate sigmoidal shape stretched in the plane of foliation. Pyroxene augen tend to be rolled and circular. Alteration: Fresh olivine augen suggest little alteration locally. Under binocular scope some green amphibole can be seen along foliation and replacing pyroxene, which amounts to more than 25% in one thin section.
Percent vein material: <1%.
Vein material: Not determined.

**COMMENTS:** Too mylonitized to estimate original proportions in hand specimen.

118-735B-56R-3



## UNIT 4: IRON-TITANIUM OXIDE GABBRO

### Pieces 1-33

### Mylonitic Gabbro

### Pieces 1 and 2

**COLOR:** Light gray.
**LAYERING:** None.
**DEFORMATION:** Intense, small rotated augen of pyroxene in very thin plagioclase-amphibole banding. Augen extend up to 3 mm to less than 1 mm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Strong.
Percent replacement: Extensive

Clinopyroxene—Mode: 40%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Strong.
Percent replacement: Extensive to 10%

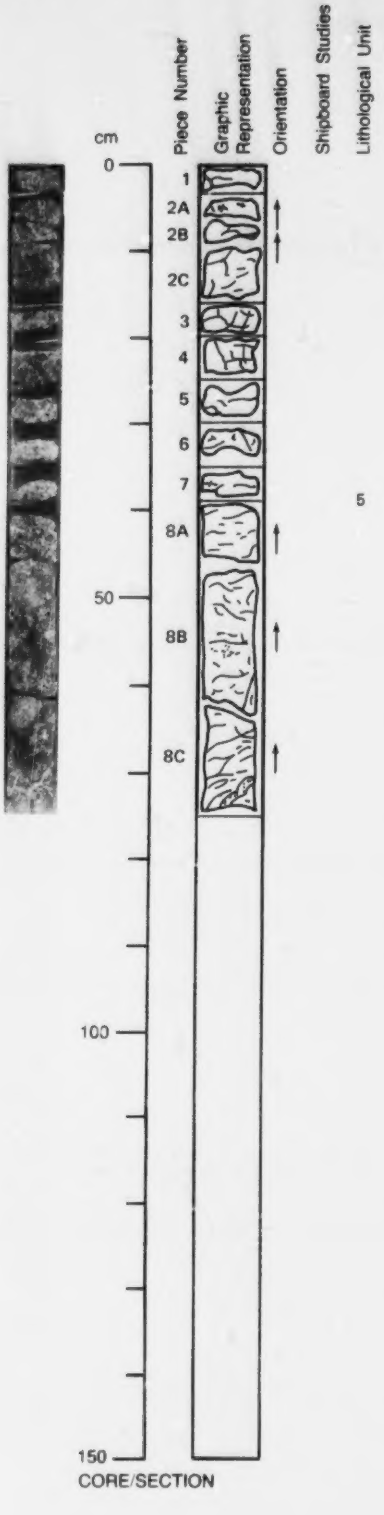
Olivine—Mode: Trace amounts.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: Strong.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Chlorite along fault planes. Amphibole replaces pyroxene. Chalcopyrite-pyrite in Piece 2.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Primary mineralogy is very approximate.

### Poorly to Well-Foliated Metagabbro

### Pieces 3-33

**COLOR:** Dark to medium green.
**LAYERING:** None.
**DEFORMATION:** Variable, from brecciated to poorly developed foliation to well developed foliation. Plagioclase and pyroxene are flattened.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 20%-50%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not evident.
Percent replacement: Slight. Plagioclase is granulated and partly epidotized

Clinopyroxene—Mode: 50%-60%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral, lens.
Preferred orientation: Weak.
Percent replacement: 80% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic. Amphiboles replace clinopyroxene. Epidote (yellow-green) replaces plagioclase, about 30%. Iron oxides (black) <5% in all pieces. Sulfides in Pieces 10, 11, 19, 22, 26, 28, and 29 (chalcopyrite).
Percent vein material: Not determined.
Vein material: Plagioclase, quartz, epidote, actinolite, and colorless fibrous (hair-like) minerals (tremolite?).
**COMMENTS:** Piece 33 is porphyroclastic.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CORE/SECTION

**118-735B-56R-4**

## UNIT 5: OLIVINE GABBRO

**Pieces: 1-8C**

**Gabbro (brecciated)**

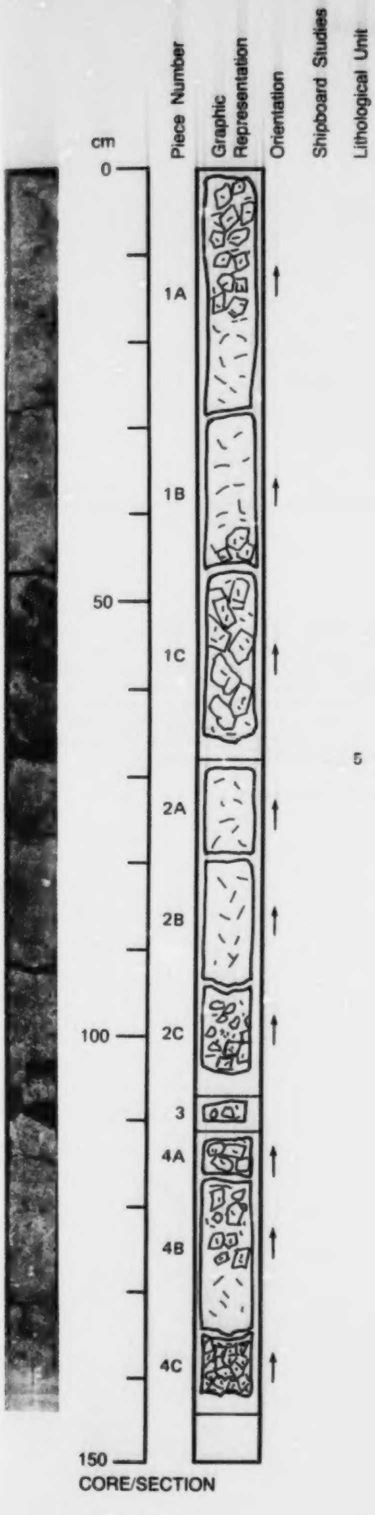
**Pieces 1-8C**

**COLOR:** Greenish gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 60%.
  Crystal size: 1-5 mm.
  Crystal shape: Anhedral.
  Preferred orientation: Not apparent.
  Percent replacement: Slight

- Clinopyroxene—Mode: 40%.
  Crystal size: 2-4 mm.
  Crystal shape: Euhedral.
  Preferred orientation: Not apparent.
  Percent replacement: Moderate.

**SECONDARY MINERALOGY:**
- Total percent: 50%.
  Texture: Amphibole replaces pyroxene along cracks, cleavage planes or margins.
  Percent vein material: Not determined.
  Vein material: Plagioclase, amphibole, and prehnite(?). Veins are filled by plagioclase and amphibole in Pieces 2A, 2B, 2C, and 8B. A light green fibrous mineral in a cavity of Piece 8B could be prehnite. Plagioclase has a green color.

### 118-735B-57R-1



**UNIT 5: OLIVINE GABBRO**

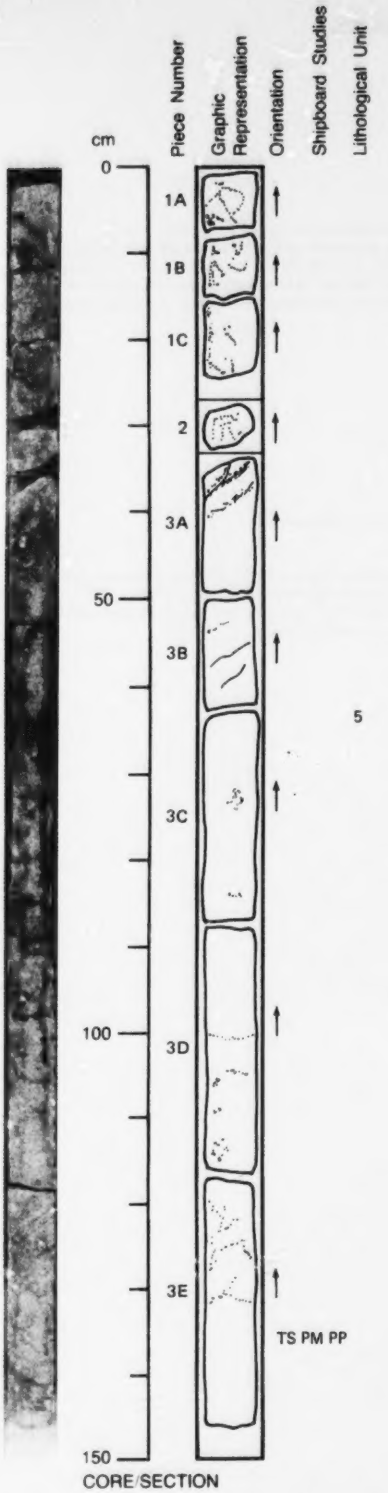
**Pieces: 1A-4C**

**Gabbro and Gabbro Breccia**

**Pieces 1A-4C**

**COLOR:** Gray.
**LAYERING:** None obvious; a little olivine concentrated at 25-28 cm.
**DEFORMATION:** Gabbroic blocks are broken up into clasts and grains with a white "veining" between blocks in the intervals 0-15, 44-66, 95-125, and 135-140 cm. Clasts range from 2 mm pyroxene grains to 5 cm blocks of intact gabbro. "Veining" is largely granulated plagioclase. Where the veins are largest, rock is disaggregated into pyroxene grains floating in a plagioclase matrix.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Not determined

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1-4 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Some amphibole after clinopyroxene.
**SECONDARY MINERALOGY:**
Total percent: Various.
Texture: Some amphibole after clinopyroxene. There is about 2% void space from pyroxene breakup and alteration. Actinolite and feldspar grains occur growing into a void at 3 cm. Some of the plagioclase has been recrystallized. All of the olivine has been pseudomorphed by talc; these pseudomorphs swell out of the core when it is wet.
Percent vein material: Not determined
Vein material: Not determined.



**118-735B-57R-2**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-3E**

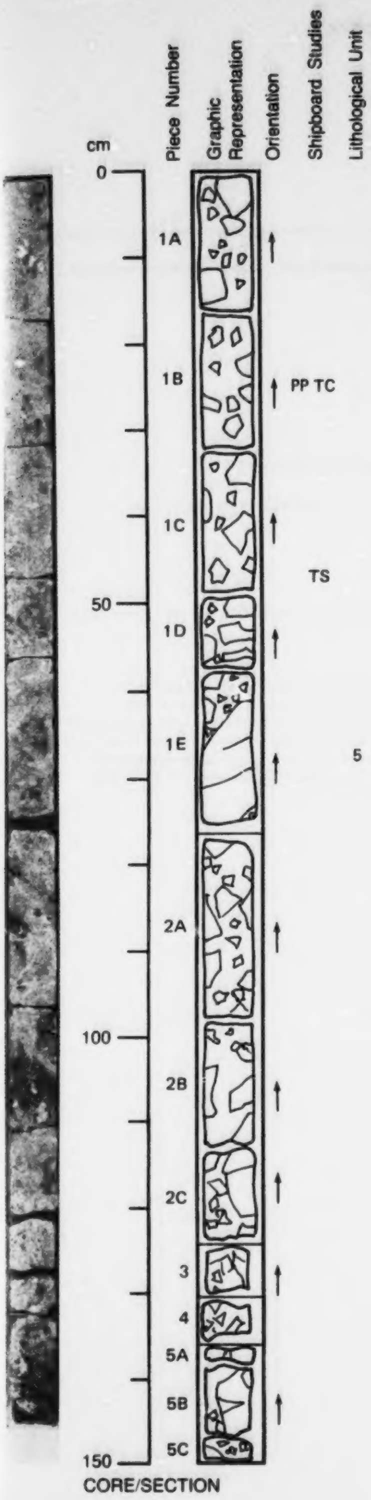
**Olivine Gabbro**

**Pieces 1A-3E**

**COLOR:** Gray (mottled gray to white due to alteration).
**LAYERING:** None apparent.
**DEFORMATION:** No apparent foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <1 mm to 1 cm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: None.
Percent replacement: Slight to moderate

Clinopyroxene—Mode: 45%-50%.
Crystal size: 1 mm to 1 cm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: Slight to moderate

Olivine—Mode: 0%-5%. Olivine most abundant in Piece 3C. None observed above 40 cm.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Slight to moderate.
**SECONDARY MINERALOGY:**
Total percent: Slight to moderate.
Texture: Amphibole replaces rims of clinopyroxene and forms diffuse network throughout most of section. Plagioclase locally has a milky white appearance particulary in Pieces 1A-C, 2, top of 3A, bottom of 3D, and 3E. Some may be altered plagioclase to Na-plagioclase, but some appears to be mechanical granulation of feldspar. Particularly well-developed around veins at top of Piece 3A. Olivine partially altered to dark mineral, maybe clay or serpentine. Larger veins in Piece 1A-C and Piece 3A include chlorite + plagioclase + epidote(?). Traces of sulfides throughout. Intense granulation in some areas between 0-40 cm yield small, even grain sizes. Mixture of light and dark minerals produces spotty appearance.
Percent vein material: Not determined.
Vein material: Na-plagioclase, chlorite, amphibole, and epidote(?).



**118-735B-57R-3**

**UNIT 5: OLIVINE GABBRO**

**Piecus 1A-5C**

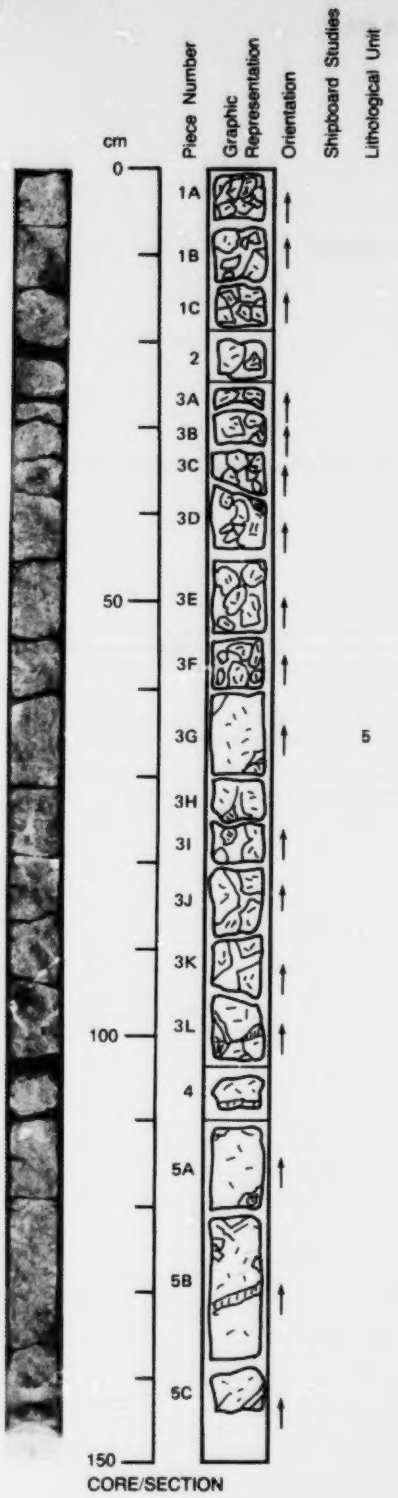
**Autoclastic Gabbro Breccia**

**Pieces 1A-5C**

**COLOR:** Gray-white.
**LAYERING:** None.
**DEFORMATION:** Brecciated with albite or sodic plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Medium to coarse.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: Not determined

Clinopyroxene—Mode: 44%.
Crystal size: Medium to coarse.
Crystal shape: Subophitic.
Preferred orientation: None.
Percent replacement: Not determined, but locally extensive to amphibole and chlorite

Olivine—Mode: 1%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100%.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Between 120 and 150 cm the alteration is much more intense with pyroxene fragments altered to dark green-black amphibole and the formation of a vuggy hydrothermal vein containing abundant brown clinozoisite, green actinolite, and chlorite in a matrix of hyrothermal feldspar and gabbro clasts.
Percent vein material: 20-40%.
Vein material: Mixture of hydrothermal and recrystallized plagioclase, mineral fragments, and amphibole with small amounts of chlorite and epidote. Possible patch of bright green talc present.
**COMMENTS:** Primary texture of gabbro clasts consists of subhophitic clinopyroxene enclosing and interlocking with subhedral to anhedral plagioclase in an equigranular texture.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CORE/SECTION

**118-735B-57R-4**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-5C**

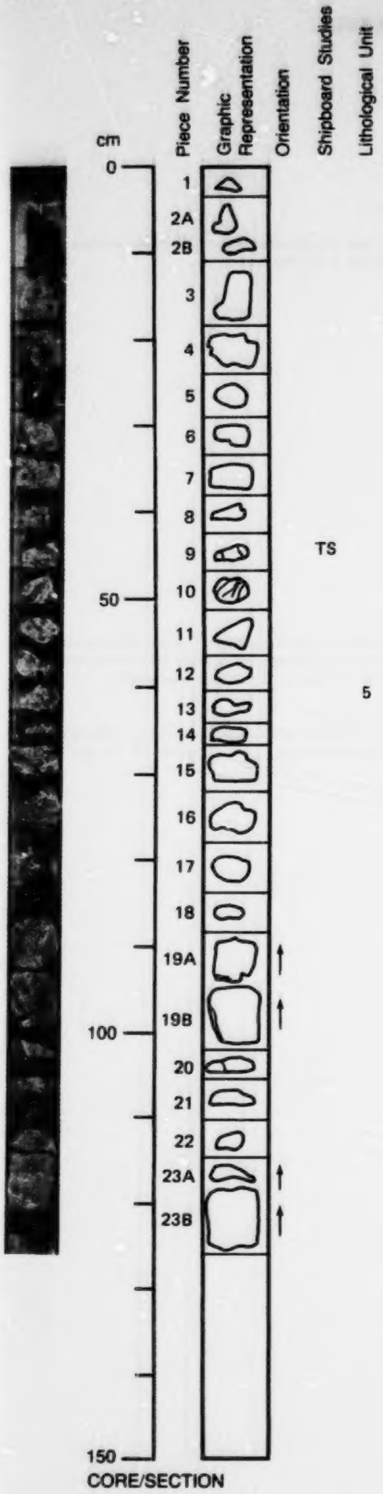
**Olivine Gabbro**

**Pieces 1A-5C**

**COLOR:** Gray with white veins and patches.
**LAYERING:** None apparent. Coarse grained throughout. Olivine scattered irregularly in 2 intervals at 38-75 cm, and 120-140 cm.
**DEFORMATION:** Broken into 3-100 mm angular fragments with zones of white-gray deformed plagioclase between them. Some veining.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-15 mm.
Crystal shape: Subhedral to anhedral, with some oikocrysts.
Preferred orientation: None.
Percent replacement: Partially amphibolitized, up to 60% in places

Olivine—Mode: 0%-3%.
Crystal size: 2-9 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: At 40-70 cm altered to chlorite/amphibole. At 120-140 cm altered to reddish-clayey clots.
**SECONDARY MINERALOGY:**
Total percent: Various.
Texture: Up to 60% of the clinopyroxene may be replaced by fine green amphibole.
Percent vein material: Concentrated at 100 cm but occur in several intervals.
Vein material: There are feldspathic veins at 100 cm, some of the thicker feldspathic intervals may be mobilized and reprecipitated feldspar. A coarse patch on the cored side includes coarse plagioclase, epidote, and actinolite in one such 5-6 mm thick segregation.
The feldspathic "veining" is probably a mix of granulated feldspar and true veins.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CORE/SECTION

**118-735B-58R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-23B**

**Altered Olivine Gabbro**

**Pieces 1-23B**

**COLOR:** Gray; gray and green-white.
**LAYERING:** None.
**DEFORMATION:** Core is breccated in places and altered (Pieces 4-6).
**PRIMARY MINERALOGY:**

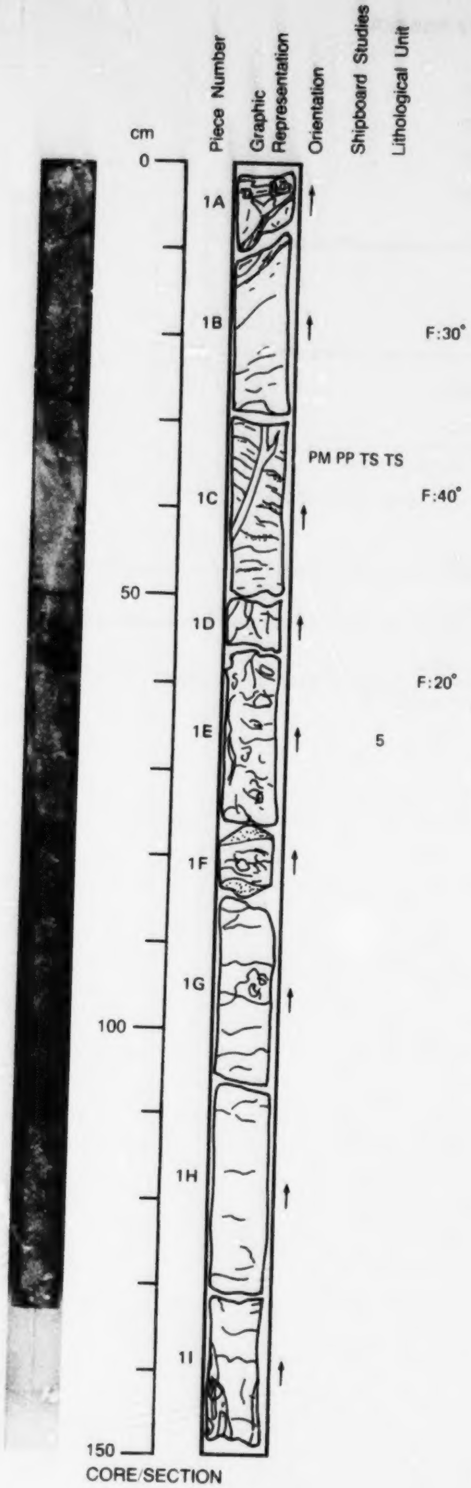
Plagioclase—Mode: 40%-60%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Commonly granulated; probably some albitization

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1-5 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Partially altered to amphibole

Olivine—Mode: 0%-8%, common in Pieces 19, 21, and 23.
Crystal size: 1-7 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: In places replaced by oxidative pseudomorphs (red clayey patches).

**SECONDARY MINERALOGY:**

Total percent: Up to 70% in places.
Texture: Clays and amphibole after olivine. Large orange oxidative pseudomorphs probably after olivine.
Percent vein material: Not determined.
Vein material: White feldspathic veins (1-2 mm wide) common throughout. Epidote common in feldspathic veins. Must be some albitization.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CORE/SECTION

118-735B-58R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1I**

**Olivine Gabbro**

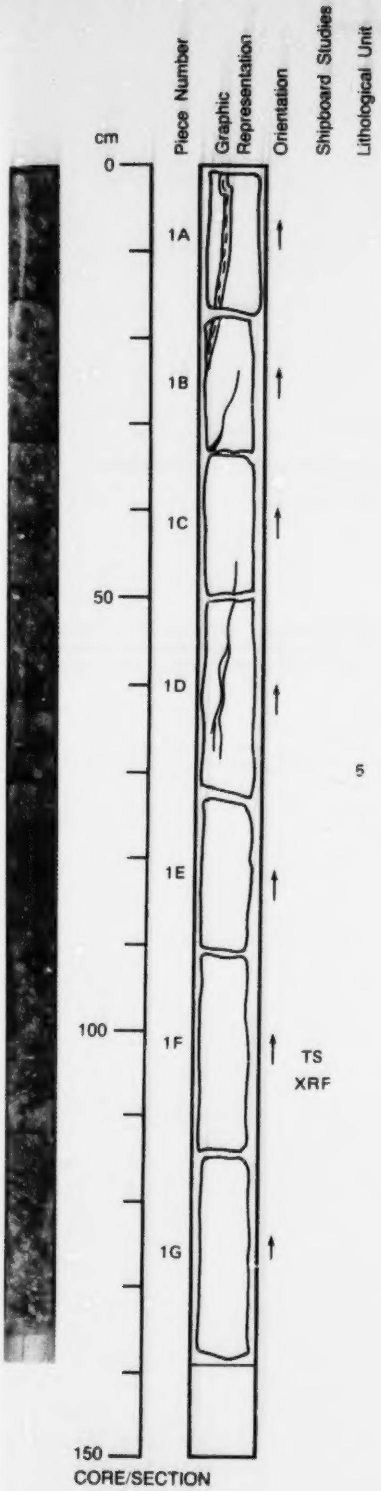
**Pieces 1A-1I**

**COLOR:** Dark gray with orange spots in Piece 1A.
**LAYERING:** Not apparent.
**DEFORMATION:** Weak foliation in Pieces 1B, 1C, and 1D; preferred orientation of plagioclase and pyroxene. Grain size is reduced from 4-6 mm to 2-3 mm on average.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: Slight

Clinopyroxene—Mode: 30%-40%.
Crystal size: 4-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: Slight

Olivine—Mode: 3%-10%.
Crystal size: 1-3 mm.
Crystal shape: Rounded, anhedral.
Preferred orientation: Not visible.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic. Olivine is replaced by orange iron hydroxide and brown clays. In other places it is replaced by dark chlorite. Clinopyroxene is partially replaced by amphibole. Plagioclase is partially replaced by epidote and secondary plagioclase (albite).
Percent vein material: Not determined.
Vein material: Plagioclase, epidote, and amphibole.
Veins, 3-4 mm thick, or pickets 1 cm thick are filled with plagioclase and epidote. Cracks are filled with sheared amphiboles. Disseminated sulfides in Pieces 1C, 1E, 1G, 1H, and 1I (pyrite) are mainly in small cracks.

**118-735B-58R-3**



## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1G**

**Olivine Gabbro**

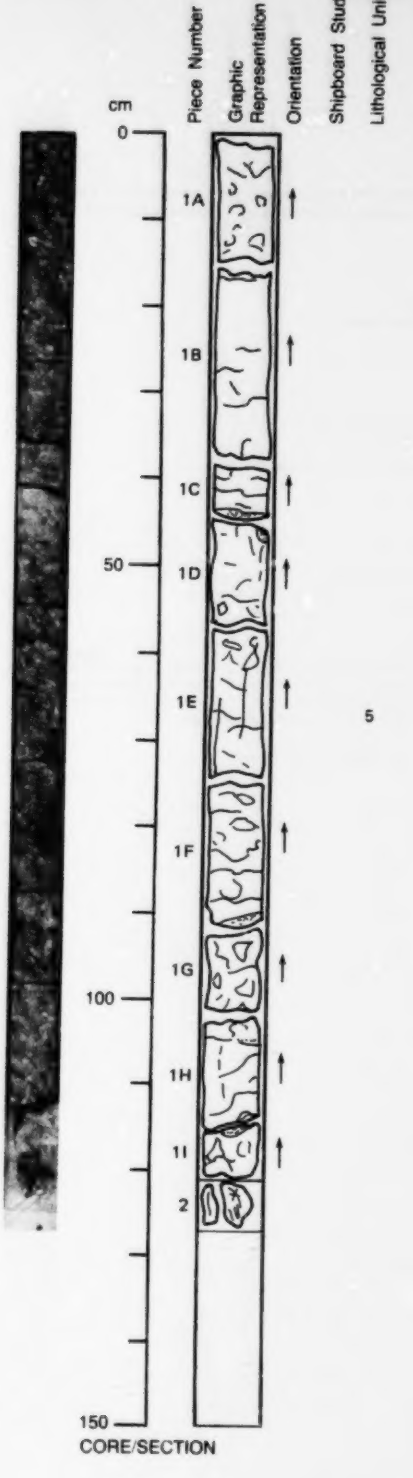
**Pieces 1A-1G**

**COLOR:** Gray.
**LAYERING:** Grain size varies along section from moderately coarse to less coarse. Locally there are suggestions of a faint subhorizontal igneous lamination due to oriented plagioclase (particularly in Piece 1A).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 2-20 mm.
Crystal shape: Granular anhedral to subhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 25%-30%.
Crystal size: 2-20 mm.
Crystal shape: Granular anhedral to subhedral.
Preferred orientation: None.
Percent replacement: <1% by magnetite and amphibole.

Olivine—Mode: 10%-20%.
Crystal size: 2 mm.
Crystal shape: Granular anhedral.
Preferred orientation: None.
Percent replacement: 0.5% by tremolite and clay.

Iron oxides and sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: 2%.
Texture: Secondary minerals are tremolite, clay, magnetite, and amphibole. Subophitic granular with disseminated sulfides through the rock in minor amounts. Large thick (about 1 cm) subvertical vein running down Pieces 1A-D, containing plagioclase, epidote, actinolite, and clinozoisite. No apparent signigicant alteration of gabbro around vein.
Percent vein material: 1%.
Vein material: Plagioclase, epidote, actinolite, and clinozoisite.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CORE/SECTION

**118-735B-59R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-2**

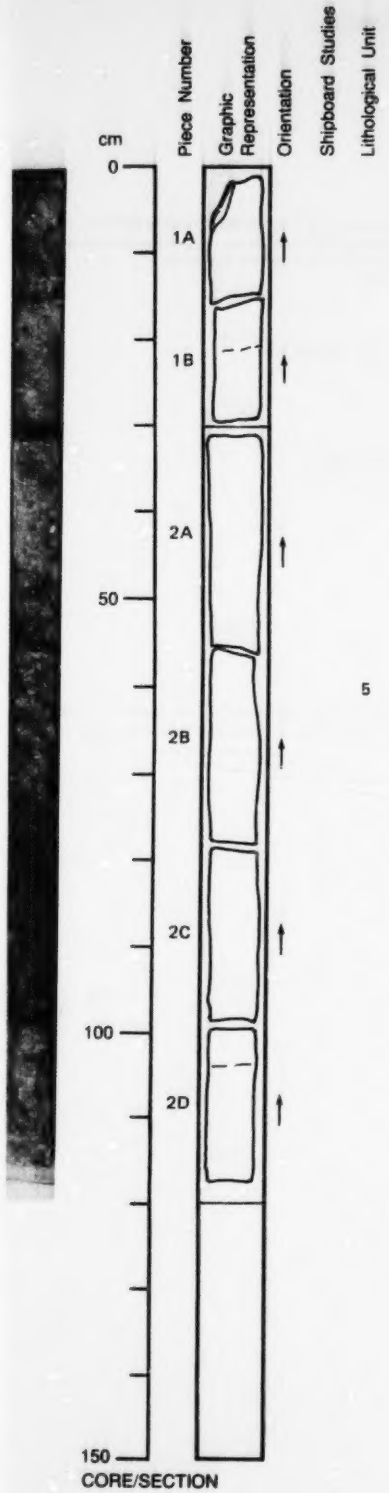
**Gabbro and Olivine Gabbro**

**Pieces 1A-2**

**COLOR:** Gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Prismatic to anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-11 mm.
Crystal shape: Anhedral to euhedral, oikocrystic.
Preferred orientation: None.
Percent replacement: Completely in Pieces 1H and 1I, otherwise slightly altered.

Olivine—Mode: 2%-10% (mostly at the base of section).
Crystal size: Not determined.
Crystal shape: Rounded.
Preferred orientation: Not defined.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Pseudomorphic. Slight replacement of pyroxene by amphibole; olivine altered (Pieces 1H and 1I) to magnetite and clay (chlorite?). Sulfides (chalcopyrite) disseminated throughout the section are mainly around silicates. Cracks are filled with amphibole(?) and a white mineral.
Percent vein material: Not determined.
Vein material: Sulfides and amphibole.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Orientation
Shipboard Studies
Lithological Unit
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CORE/SECTION

**118-735B-59R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-2D**

**Olivine Gabbro**

**Pieces 1A-2D**

**COLOR:** Gray.
**LAYERING:** Grain size seems to decrease downward in an 80 cm thick layer from 20 to 104 cm.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 0%.

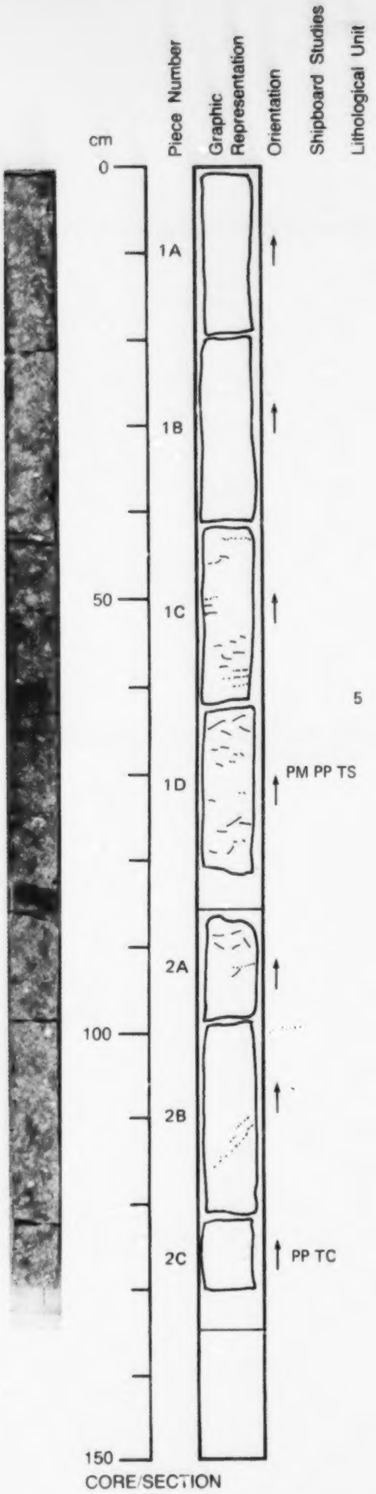
Clinopyroxene—Mode: 30%.
Crystal size: 5-30 mm.
Crystal shape: Subophitic.
Preferred orientation: None.
Percent replacement: 0%.

Olivine—Mode: 10%-15%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%.

Iron Oxides—Mode: <1%.
Sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**
Total percent: 0%.
Texture: Not determined.
Percent vein material: <1%.
Vein material: Talc(?) and chlorite.

**COMMENTS:** Subhedral granular texture with subophitic clinopyroxene partially enclosing subhedral plagioclase. Clinopyroxene is intergrown with subordinate olivine.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Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1D
2A
2B
2C
5
PM PP TS
PP TC
CORE/SECTION

**118-735B-59R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-2C**

**Olivine Gabbro**

**Pieces 1A-2C**

**COLOR:** Gray.

**LAYERING:** Some grain size variation, mostly coarse grained. One graded interval at 90-65 cm. Some very coarse-, fine-, and medium-grained layers. Size changes are not sharply defined. A plagioclase-rich band occurs at 61 cm and some large olivine at 121 cm.

**DEFORMATION:** None. A few subhorizontal fractures.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%-30%.
Crystal size: 2-14 mm.
Crystal shape: Euhedral (inside clinopyroxene) to anhedral.
Preferred orientation: None.
Percent replacement: 0%

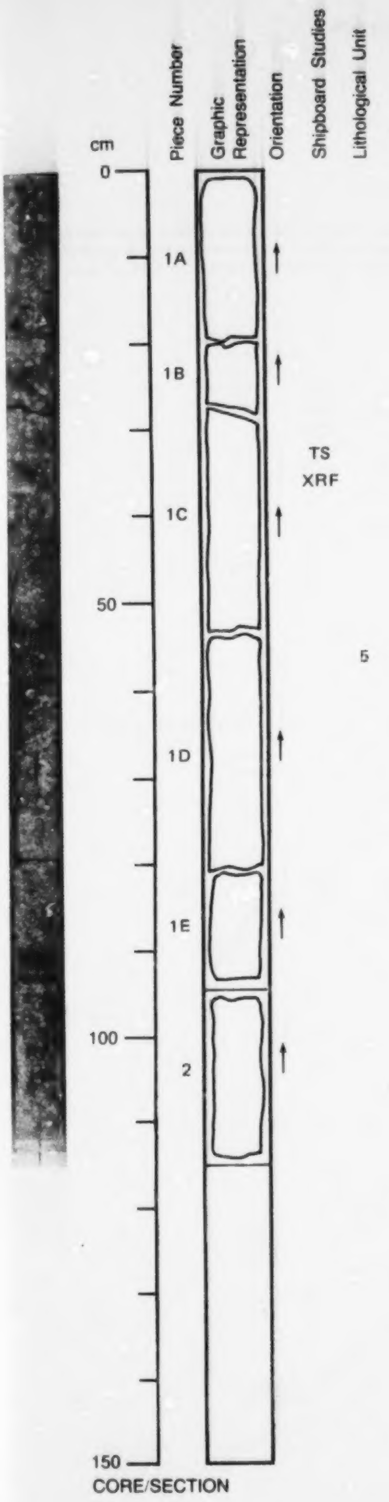
Clinopyroxene—Mode: 40%-70%.
Crystal size: 3-20 mm.
Crystal shape: Subhedral to anhedral, oikocrysts.
Preferred orientation: None.
Percent replacement: Minor amphibolitization

Olivine—Mode: 10%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Very minor.

**SECONDARY MINERALOGY:**

Total percent: <2%.
Texture: Minor amphibolitization.
Percent vein material: Not determined.
Vein material: Not determined.

**COMMENTS:** Rock is so fresh that olivine is hard to distinguish—likely more common than noted in some sections. Fine (<1 mm) pyrite common (though <1%) at pyroxene interstices.


cm
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CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1A
1B
1C
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2
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XRF
5

### 118-735B-59R-4

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-2**

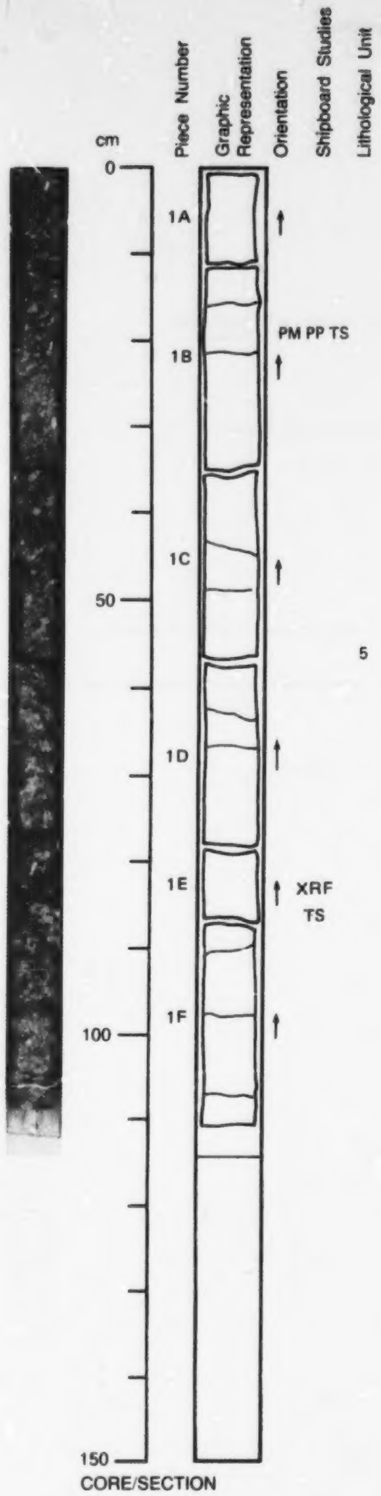
**Olivine Gabbro**

**Pieces 1A-2**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 0.5-2 cm.
Crystal shape: Anhedral to euhedral where enclosed in clinopyroxene.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 45%-40%.
Crystal size: 0.5-2 cm.
Crystal shape: Anhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 0.5-1 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 1%
**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Mainly amphibole replacement of clinopyroxene along grain boundaries.
Percent vein material: None.
Vein material: None.
**COMMENTS:** Coarse grained, fairly uniform. Traces of sulfides throughout. Traces of primary ilmenite throughout.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
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150
1A
1B
1C
1D
1E
1F
PM PP TS
XRF
TS
5
CORE/SECTION

**118-735B-60R-1**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-1F**

**Olivine Gabbro**

**Pieces 1A-1F**

**COLOR:** Gray.

**LAYERING:** Probable modal layering (bands with plagioclase enrichments and intervals with higher olivine proportions), and grain size variations. Rock is in general coarse-grained (average grain size 1.0-1.5 cm) with coarser grained intervals (plagioclase up to 3 cm, clinopyroxene up to 3 cm, olivine up to 2 cm).

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 45%-65%.
Crystal size: 0.5-3 cm.
Crystal shape: Anhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

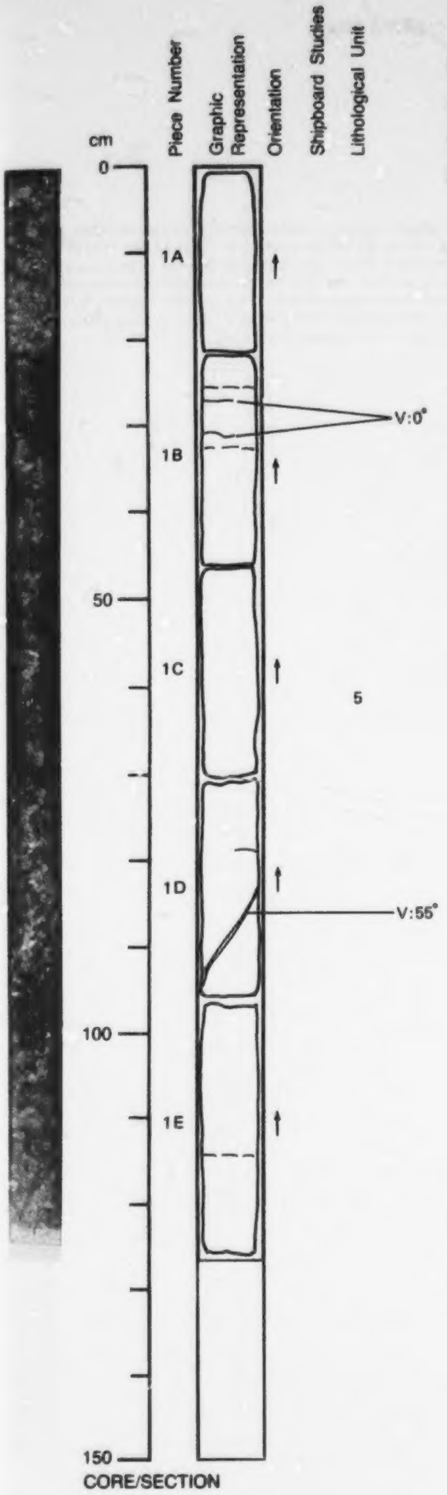
Clinopyroxene—Mode: 30%-40%.
Crystal size: 0.5-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 2%->10%.
Crystal size: 0.5-2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Very fresh rock. Olivine mostly preserved. Very minor amphibole replacement of clinopyroxene. Few veinlets.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
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100
150
1A
1B
1C
1D
1E
V:0°
V:55°
5
CORE/SECTION

## 118-735B-60R-2

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-1E**

**Olivine Gabbro**

**Pieces 1A-1E**

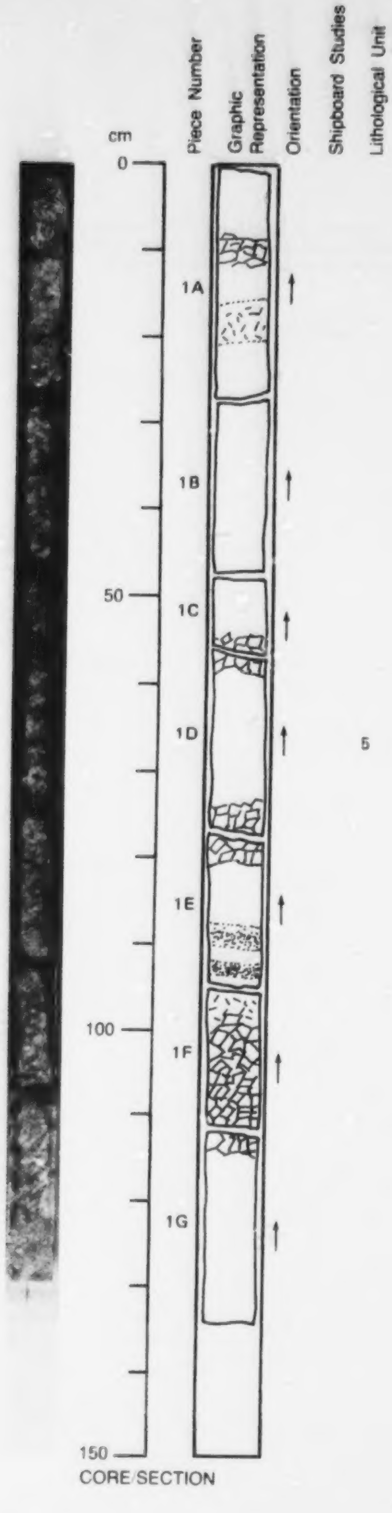
**COLOR:** Gray-green.
**LAYERING:** Grain size variation, progressive over Pieces 1C, 1D and 1E, from <10 mm to 20 mm, abrupt in Piece 1E from 20 mm to <10 mm. Possible modal layering (olivine concentration) in Piece 1B. No magmatic lamination: the crystals are not tabular, but slightly oikocrystic.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: <10-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: <10-20 mm.
Crystal shape: Oikocrystic.
Preferred orientation: None.
Percent replacement: <10% by amphibole.

Olivine—Mode: 10%-20%.
Crystal size: <10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: <10%
Texture: Minor amphibolitization of clinopyroxene, and alteration of olivine. No albitization of plagioclase, except immediately adjacent to veins.
Percent vein material: <1%.
Vein material: Amphibole.
**COMMENTS:** No significant concentrations of iron-titanium oxide.



118-735B-80R-3

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-1G**

**Olivine Gabbro**

**Pieces 1A-1G**

**COLOR:** Gray.

**LAYERING:** Size and texture variations suggest layering. Coarse-grained ophitic (oikocrystic); (orthocumulate) 10-30 cm thick intervals at 0-8, 12-16, 21-53, 60-73, 81-88, and 115-135 cm; plagioclase: 1-2.5 cm, clinopyroxene: anhedral. Coarse-grained granular (mesocumulate) 20-5 cm thick intervals at 8-12, 53-60, 73-81, and 95-115 cm; plagioclase and clinopyroxene: 1-3 cm, clinopyroxene: subhedral. Medium-grained ophitic, 5-2 cm thick intervals at 16-21 and 88-95 cm; plagioclase: 0.5-1 cm, clinopyroxene: anhedral Layer contacts are gradational. Mostly coarse-grained ophitic. Inclination not clear (horizontal?).

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: See above.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Not clear.
Percent replacement: None.

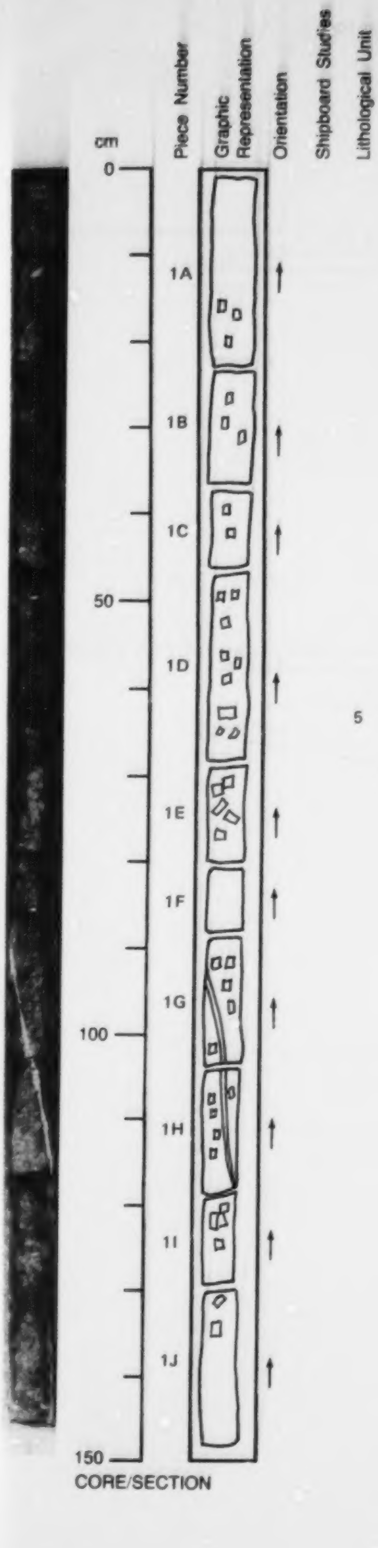
Clinopyroxene—Mode: 30%.
Crystal size: See above.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: Almost none.

Olivine—Mode: 2%-10%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: Almost none.

**SECONDARY MINERALOGY:**

Total percent: Trace or none. Very fresh!
Texture: Not determined.
Percent vein material: None.
Vein material: None.

118-735B-60R-4


cm
Piece Number
Graphic Representation
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Shipboard Studies
Lithological Unit
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CORE/SECTION

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1K**

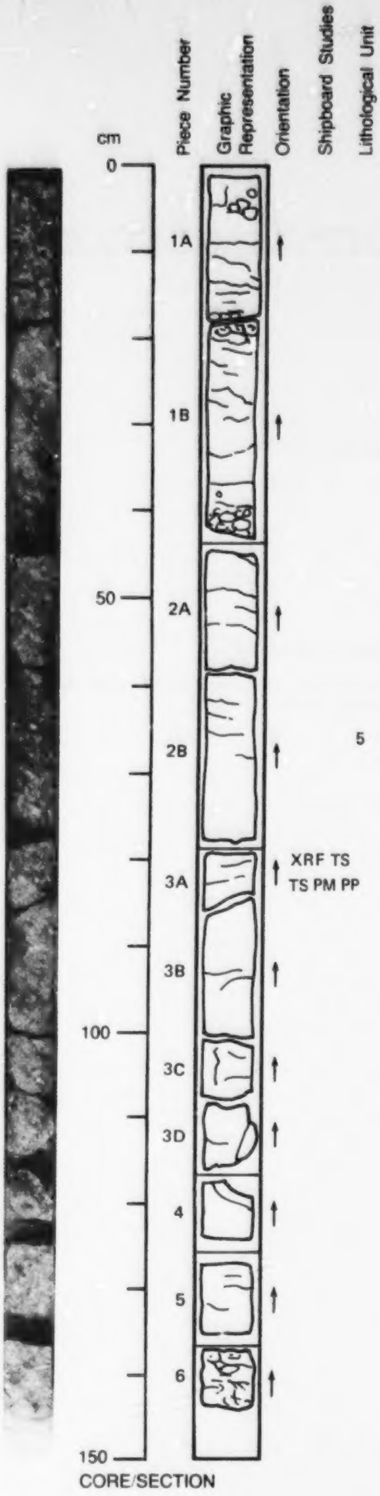
**Olivine Gabbro**

**Pieces 1A-1K**

**COLOR:** Gray.
**LAYERING:** Size grading. Clinopyroxene varies from average of 5 mm to average of 15 mm. Plagioclase varies from average of 5 mm to average of 20 mm. Variation occurs over 50-60 cm interval.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-65%.
Crystal size: 5-25 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: 5-30 mm.
Crystal shape: Subhedral, granular to oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Minor replacement of clinopyroxene by amphibole.
Percent vein material: Not determined.
Vein material: 1 cm wide vein through Pieces 1G and 1H lined with amphibole and filled with plagioclase, quartz, and green amphibole (actinolite) in the center.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XRF TS
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CORE/SECTION

**118-735B-81R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-6**

**Olivine Gabbro**

**Pieces 1A-6**

**COLOR:** Gray.

**LAYERING:** Only faint, if there is any. Rock is, in general, coarse-grained (on average 1.0-1.5 cm) with some coarser intervals. Minor variation in olivine contents.

**DEFORMATION:** In general undeformed. Weakly brecciated in Pieces 3D and 4.

**PRIMARY MINERALOGY:**

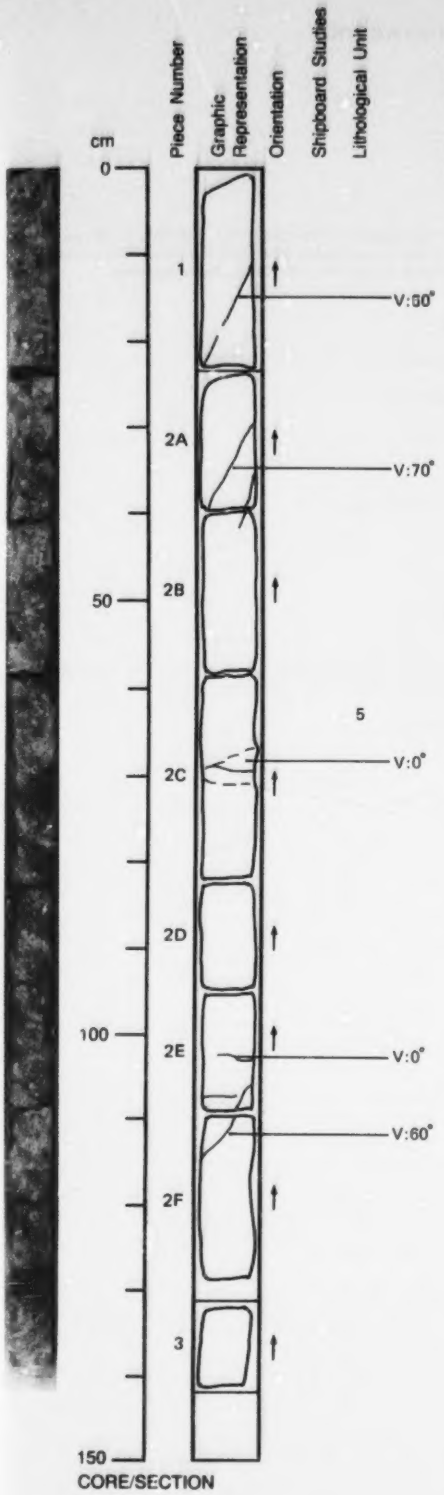
Plagioclase—Mode: 55%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 3%-8%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight alteration.
Texture: Amphibole forms rims around clinopyroxene. Olivine mostly fresh. Moderate alteration in Pieces 3D and 4 along a brecciated zone. Few sulfides.
Percent vein material: Not determined.
Vein material: Some veinlets, filled with white mineral(s).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V:70°
V:0°
V:0°
V:60°
5
CORE/SECTION

## 118-735B-61R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1-3**

**Olivine Gabbro**

**Pieces 1-3**

**COLOR:** Gray.
**LAYERING:** None apparent, no igneous lamination. Mean grain size varies from ≤20 mm in Piece 1, to ≤15 mm in Piece 2A, to ≤10 mm in Pieces 2B and 2C, to ≤8 mm in Piece 3.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

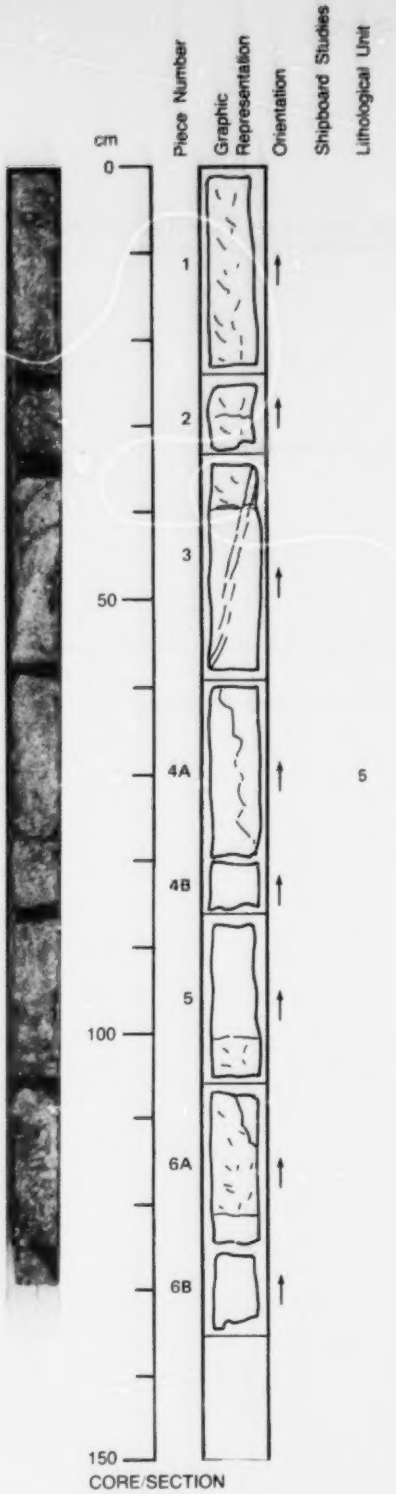
Plagioclase—Mode: 50%-60%.
Crystal size: <8-20 mm.
Crystal shape: Tabular.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: <8-20 mm.
Crystal shape: Semi-oikocrystic with plagioclase tablets included.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: <8-20 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Pyroxene amphibolitized especially close to veins, and in Piece 3. Olivine altered partially.
Percent vein material: <1%.
Vein material: Amphibole veins dip 60°-70°. Also, thin subhoriozontal white veins.


cm
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Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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6A
6B
5
CORE/SECTION

**118-735B-61R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-6B**

**Olivine Gabbro**

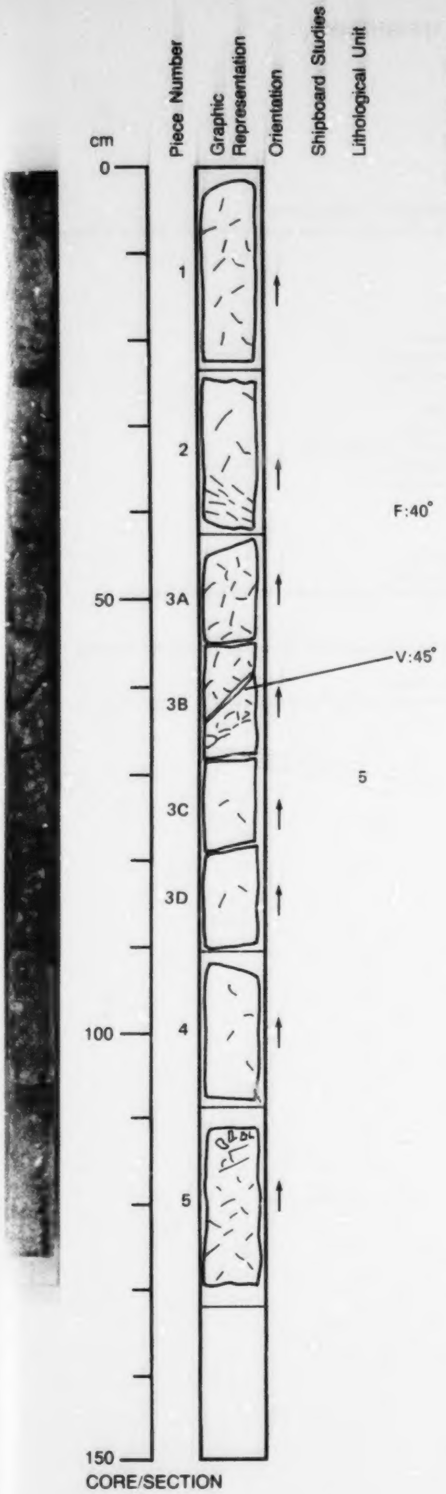
**Pieces 1-6B**

**COLOR:** Gray to greenish-gray.
**LAYERING:** Grainsize layering: 0-40 cm, coarse-grained (clinopyroxene = 4-10 mm); 40-100 cm, medium grained, gradually increasing in size toward bottom of interval; 100-120cm, very coarse-graine with poikilitic texture (clinopyroxene = 5-20 mm); 120-135 cm, medium-grained.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 2-22 mm.
Crystal shape: Subhedral to poikilitic.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: 2-30 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 10-15% by amphibole.

Olivine—Mode: 5%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10-15% by talc.
**SECONDARY MINERALOGY:**
Total percent: 12%.
Texture: Clinopyroxene is replaced by green amphibole around the rims. The alteration halos are broader at the bottom of the core. Olivines are partially replaced by talc.
Percent vein material: 4%.
Vein material: Hornblende and albite.

## 118-735B-61R-4



### UNIT 5: OLIVINE GABBRO

**Pieces 1-5**

**Olivine Gabbro**

**Pieces 1-5**

**COLOR:** Gray.

**LAYERING:** Size and textural (+ modal) variations suggest layering.

1) Graded layer in Pieces 1 and 2, where grain size increases and olivine is more abundant downward. Clinopyroxene: 25 mm, average 10 mm; olivine: 3-10 mm, average 6 mm; plagioclase: 5-20 mm, average 10 mm. Olivine = 5%-10%, clinopyroxene = 35%-40%, top; olivine = 15%, clinopyroxene = 20%, bottom.

2) Well-foliated layer in Piece 2. Olivine: 8 mm, 15-20%; clinopyroxene: 8 mm, 15%; plagioclase: 15 mm,

3) Medium-coarse-grained ophitic in Pieces 3A, 3B, and 5. Plagioclase: 15 mm, 60%; clinopyroxene: 10 mm, 35%; olivine: 4-5 mm, 5%.

4) Coarse-grained locally ophitic in Pieces 3B, 3C, 3D, 4, and 5. Plagioclase: 5-50 mm, average 15 mm, 60%; clinopyroxene: 5-30 mm, average 12 mm, 35%; olivine: 5-20 mm, average 10 mm, 5%.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

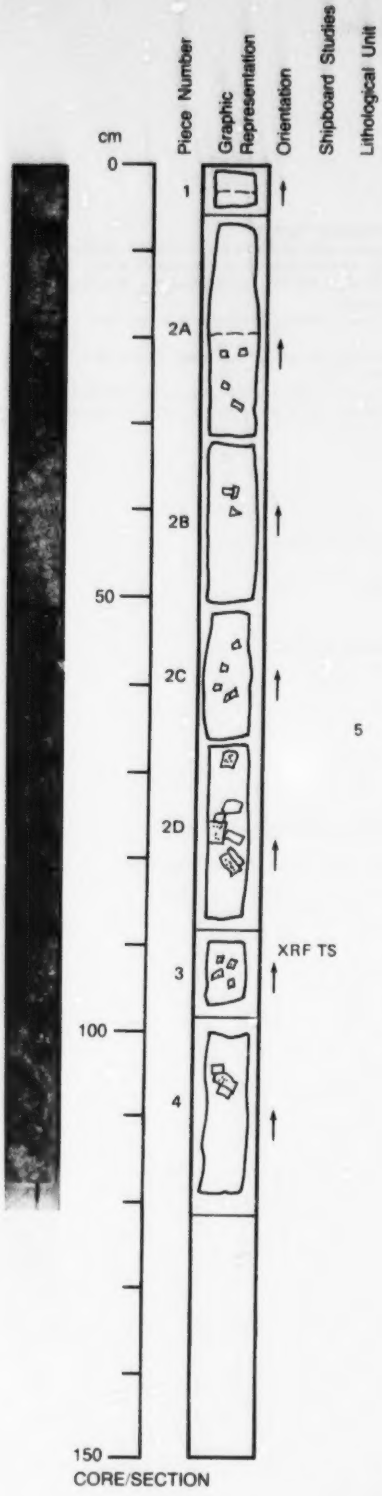
Plagioclase—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None except for Piece 2 (bottom).
Percent replacement: None.

Clinopyroxene—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Anhedral.
Preferred orientation: None except for Piece 2 (bottom).
Percent replacement: Trace by amphibole

Olivine—Mode: Variable, see above.
Crystal size: Variable, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Trace.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Clinopyroxene and olivine are replaced by amphibole (5% or less).
Percent vein material: Trace.
Vein material: Amphibole vein is present in Piece 3B dipping 45°, 1 mm thick.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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150
1
2A
2B
2C
2D
3
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XRF TS
5
CORE/SECTION

## 118-735B-62R-1

### UNIT 5: OLIVINE GABBRO

**Pieces 1-4**

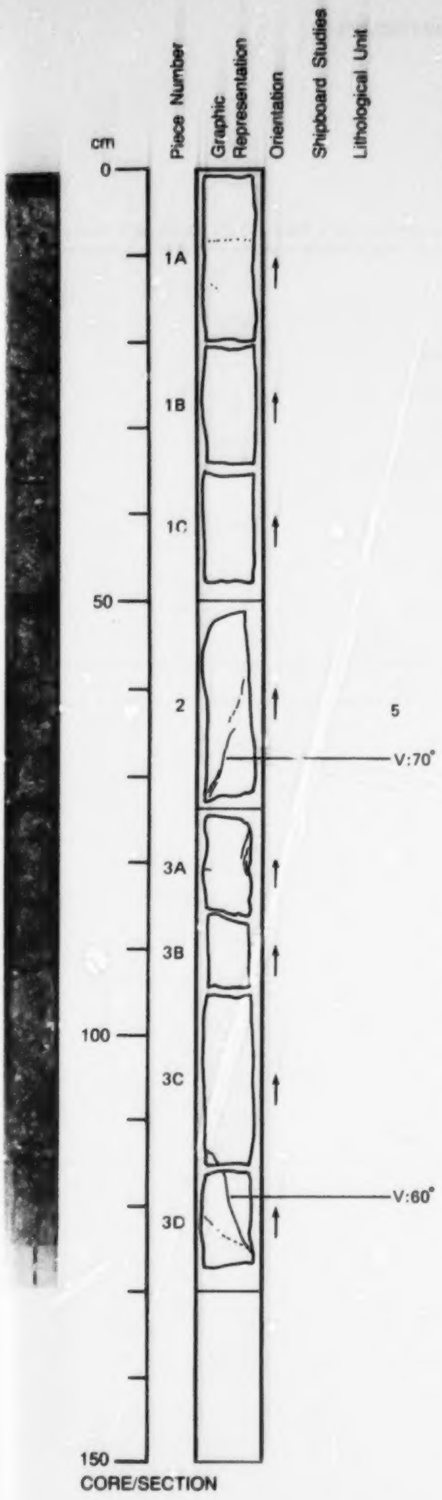
**Olivine Gabbro**

**Pieces 1-4**

**COLOR:** Gray on sawn surface, greenish gray on cored surface.
**LAYERING:** Weak igneous lamination in Piece 2D, increase in grain size from bottom of Piece 2A to 2
and from Piece 3 to 4.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-65%.
Crystal size: 8-25 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-40%.
Crystal size: 8-25 mm (up to 30 mm).
Crystal shape: Subhedral-euhedral, rare oikocrysts.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-15%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined; partly replaced by tremolite + talc(?).
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Trace amounts of sulfide associated with amphibole. Amphibole replacing clinopyroxene.
Percent vein material: Not determined.
Vein material: Common subhorizontal veins (<0.5 mm thick) of sodic plagioclase(?).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V:70°
V:60°
CORE/SECTION

118-735B-62R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3D**

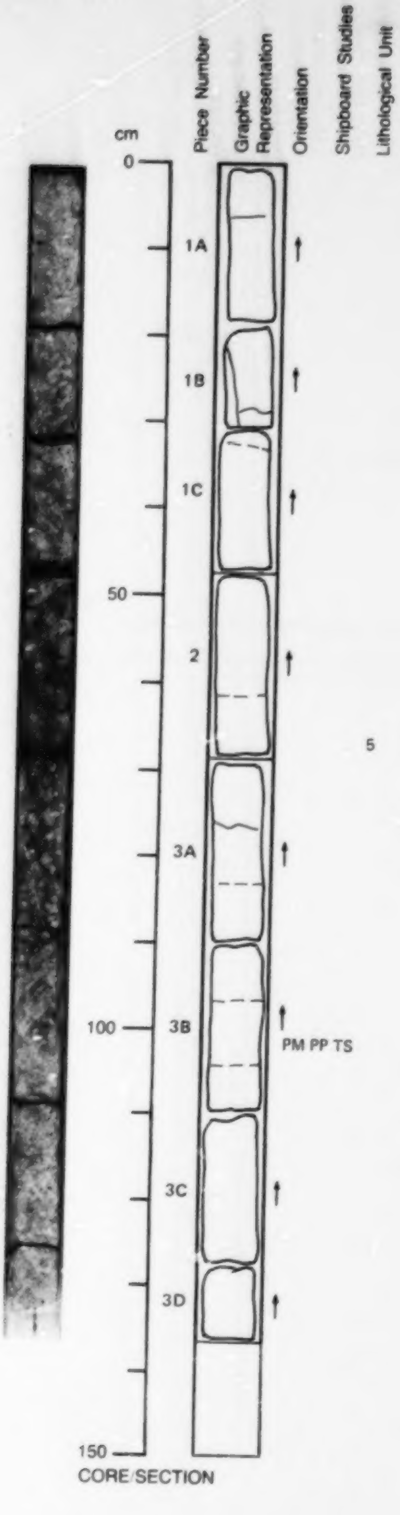
**Olivine Gabbro**

**Pieces 1A-3D**

**COLOR:** Gray.
**LAYERING:** None, minor variations in grain size.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 2-10 mm.
Crystal shape: Tabular.
Preferred orientation: None.
Percent replacement: 0%.

Clinopyroxene—Mode: 43%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 30% by green amphibole.

Olivine—Mode: 2%-5%.
Crystal size: <1 mm.
Crystal shape: Interstitial.
Preferred orientation: None.
Percent replacement: >50% by talc.
**SECONDARY MINERALOGY:**
Total percent: 20%.
Texture: Chlorite is present. Disseminated sulfides, often enclosed in amphibole.
Percent vein material: 2%.
Vein material: Hornblende and plagioclase; Veins in Pieces 3C and 3D are filled by a soft white mineral. Vein in Piece 2 is filled by amphibole and a white mineral.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CORE/SECTION

**118-735B-62R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3D**

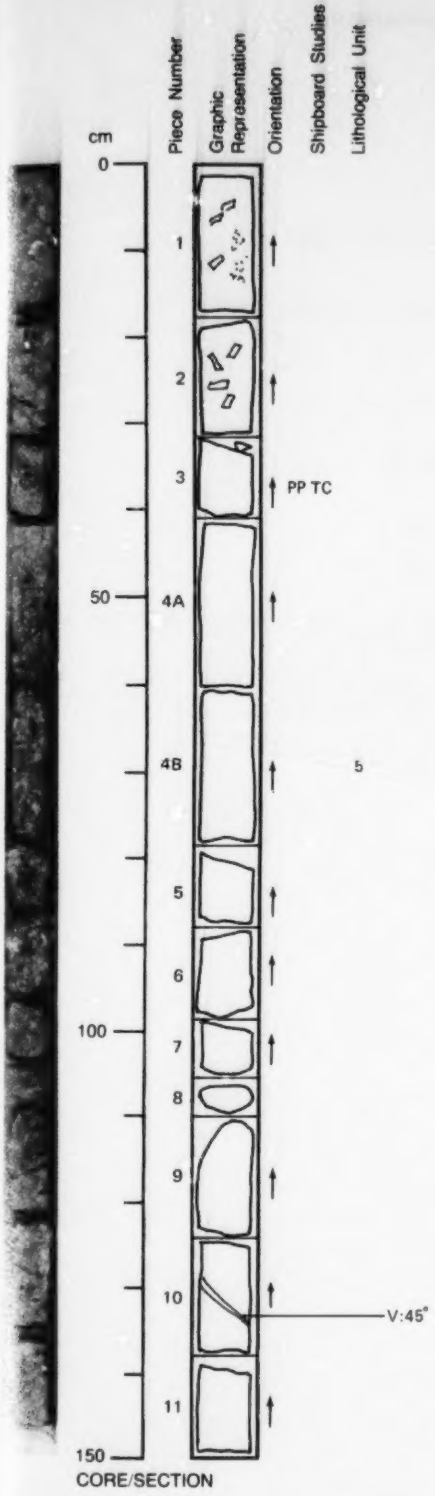
**Olivine Gabbro**

**Pieces 1A-3D**

**COLOR:** Gray-green.
**LAYERING:** Not clear, faint grain size variations: <1 cm in Pieces 3C and 3D, 2.5 cm in Piece 2A, 1-2.5 cm elsewhere. Variations in the modal percent of olivine are possible. No magmatic lamination.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 30%-40%.
Crystal size: See layering above.
Crystal shape: Tabular to anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 50%-60%.
Crystal size: See layering above.
Crystal shape: Anhedral, locally oikocrystic.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-15%.
Crystal size: See layering above.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <10%.
Texture: Olivine partially altered, plagioclase very fresh, pyroxene a little amphibolitized.
Percent vein material: <1%.
Vein material: Amphibole and also thin sub-horizontal white veins.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CORE/SECTION

118-735B-62R-4

## UNIT 5: OLIVINE GABBRO

**Pieces 1-11**

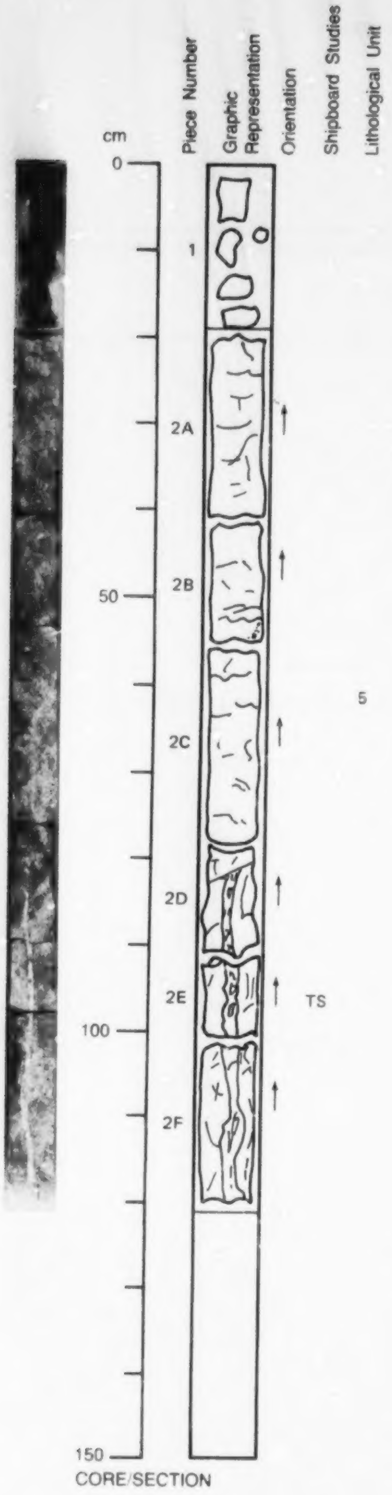
**Olivine Gabbro**

**Pieces 1-11**

**COLOR:** Gray.
**LAYERING:** Modal variation shows possible layering, but layer contacts are not marked and gradational. In Piece 1 irregular medium grained patches occur. Piece 5 is olivine-rich (20%). Weak foliation is present.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-65%.
Crystal size: 2-30 mm. <2 mm plagioclase occur as chadacrysts in oikocrystic clinopyroxene.
Crystal shape: Subhedral.
Preferred orientation: Weak.
Percent replacement: None.

Clinopyroxene—Mode: 20%-35%.
Crystal size: 5-25 mm.
Crystal shape: Anhderal.
Preferred orientation: Weak.
Percent replacement: Trace by amphibole.

Olivine—Mode: 7%-20%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Weak.
Percent replacement: Trace by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Amphibole replaces clinopyroxene and olivine.
Percent vein material: Trace.
Vein material: Amphibole vein, 1 mm thick and dipping 45° is present in Piece 10.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CORE/SECTION

**118-735B-63R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-2F**

**Olivine Gabbro (Troctolitic)**

**Pieces 1-2F**

**COLOR:** Gray.
**LAYERING:** Not apparent.
**DEFORMATION:** None apparent. In Piece 1 foliation is visible.
**PRIMARY MINERALOGY:**

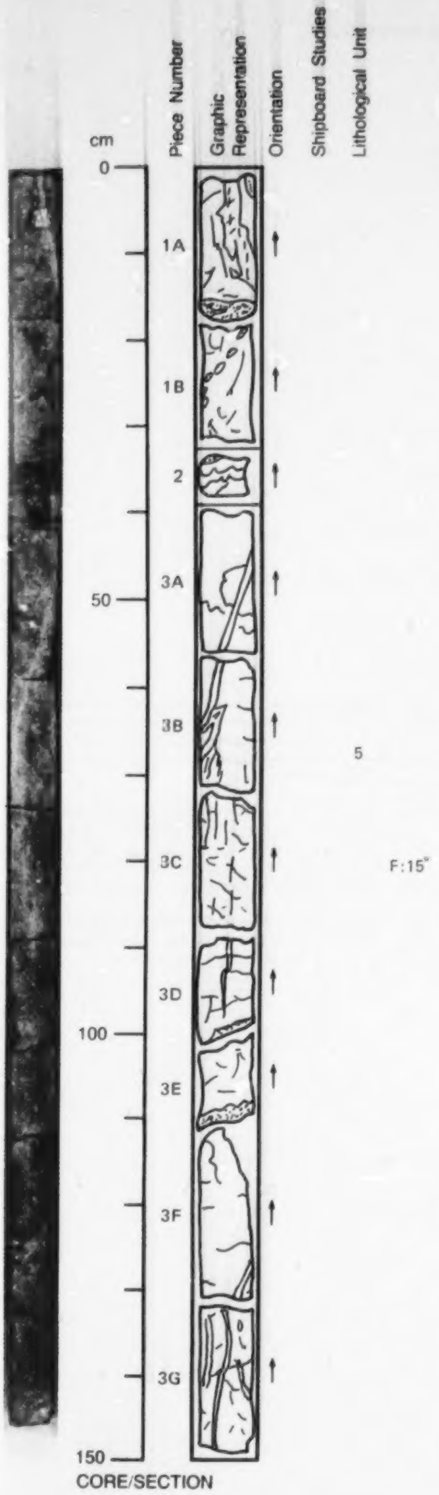
Plagioclase—Mode: 40%-50%.
Crystal size: 1-4 mm.
Crystal shape: Prismatic (enclosed in clinopyroxene).
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40%.
Crystal size: Up to 20 mm.
Crystal shape: Oikocrystic.
Preferred orientation: None.
Percent replacement: 20% by amphibole.

Olivine—Mode: 10%-20%.
Crystal size: 1-10 mm.
Crystal shape: Rounded to irregular.
Preferred orientation: None.
Percent replacement: 30% by bluish talc.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Coronitic, pseudomorphic. Olivine is 30% altered to bluish talc (coronitic reaction). Clinopyroxene is 20% replaced by amphibole.
Percent vein material: Not determined.
Vein material: Plagioclase, amphibole, and prehnite. Vein filling (4-15 mm thick) in Pieces 2D, 2E, and 2F: Plagioclase, amphibole, bluish green prehnite (botryoidal on walls of a vug), and some yellow browm epidote(?). Some quartz is present near the walls of the veins.



## 118-735B-63R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3G**

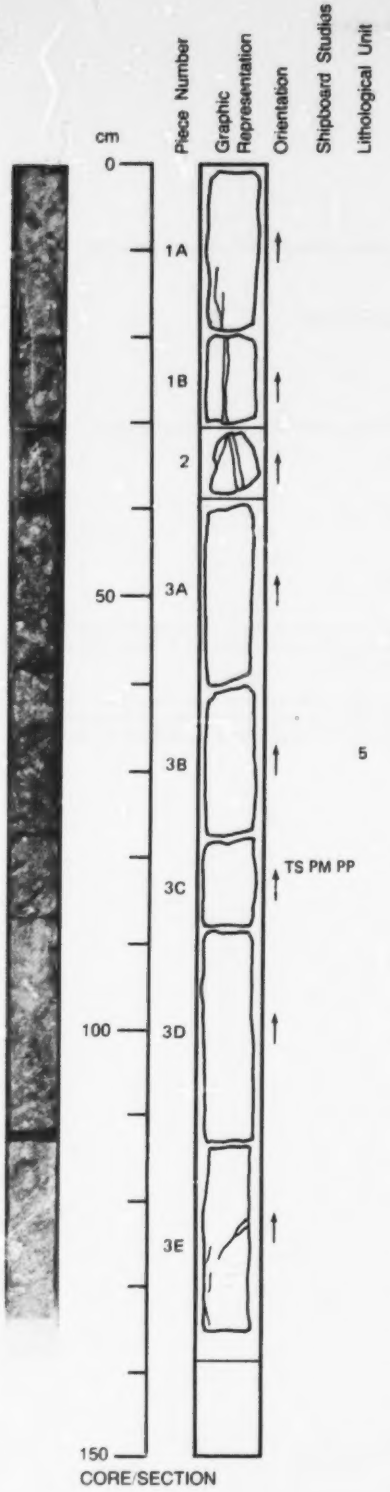
**Olivine Gabbro**

**Pieces 1A-3G**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None except for faint primary foliation developed with pyroxene flattening.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 8 mm.
Crystal shape: Euhedral (included in clinopyroxene).
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 1.5 cm.
Crystal shape: Large irregular oikocrysts with subophitic inclusions of plagioclase.
Preferred orientation: Faint.
Percent replacement: 20% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: Up to 8 mm.
Crystal shape: Euhedral to rounded.
Preferred orientation: None apparent.
Percent replacement: 20% by bluish talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic. Olivine replaced by talc (bluish color). Clinopyroxene partially (20%) replaced by dark amphibole. Fractures filled with amphiboles Piece 3G. Cracks developed in olivine (post-alteration) are filled with sulfides.
Percent vein material: Not determined.
Vein material: Plagioclase, sulfides, and epidote. Veins (3 mm-1.5 cm thick). Piece 2 filled with plagioclase, sulfides (present in the rock also), and yellow green epidote. Some copper-sulfide altered to malachite and associated with quartz. Fractures filled with talc and sulfides.



**118-735B-63R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3E**

**Olivine Gabbro**

**Pieces 1A-3E**

**COLOR:** Gray.
**LAYERING:** No clear layering.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral laths.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 3-20 mm.
Crystal shape: Anhedral intergranular to ophitic.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: Not determined.
Crystal shape: Anhedral intergranular.
Preferred orientation: None.
Percent replacement: 10-50% by talc-tremolite, 100% near veins.

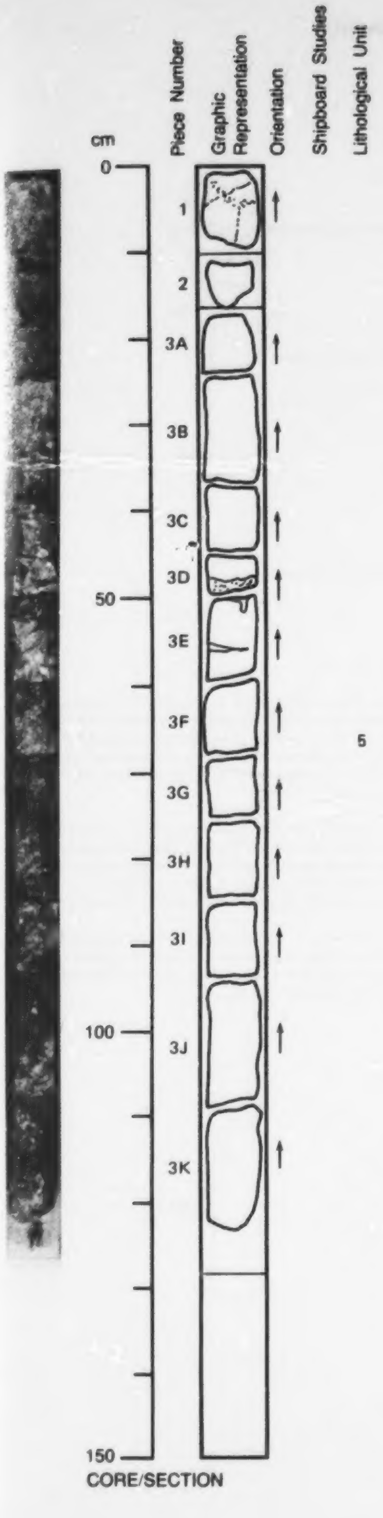
Iron-oxides—Mode: <1%.

Iron-sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Groundmass alteration appears to be largely the formation of small cross-cutting veins of amphibole which cut all the primary minerals, the alteration of olivine to form talc-tremolite or serpentine, and the rimming of clinopyroxene locally by amphibole. Alteration is most intense near the veins described below, but is generally weak. Olivine is usually 50%-90% fresh, and is totally pseudomorphed only next to the veins.
Percent vein material: <1%.
Vein material: There are two generations of veins: the first consists of 1-3 mm subvertical veins of plagioclase with accessory clinozoisite in Pieces 1A, 1B, 2, and 3A. Pyroxene next to these veins is generally altered to dark green amphibole. The second generation of veins cross-cuts the first in Piece 2 and consist of pale green talc. A single large 2 mm vein in Piece 3E seems to be a compound vein with talc and the plagioclase-zoisite-amphibole assemblages occurring locally along it.

**COMMENTS:** Equigranular olivine gabbro with a subophitic to ophitic texture with intergranular pyroxene and olivine grown around and enclosing 0.5-1.0 cm plagioclase laths. Plagioclase laths are subhedral and may be inclusions with pyroxene in larger olivine grains.

## 118-735B-63R-4



### UNIT 5: OLIVINE GABBRO

**Pieces 1-3K**

**Olivine Gabbro**

**Pieces 1-3K**

**COLOR:** Gray.

**LAYERING:** Primary layering defined by alternating grain size and modal proportions. Modal proportions vary throughout section. Interval 35-43 cm is troctolitic with 95% plagioclase and 5% olivine; interval 94-102 cm is also more plagioclase-rich, but still gabbro. Slightly coarser grained intervals between 35-47 cm and 94-103 cm. Clinopyroxene with subophitic texture partially enclosing a plagioclase.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 95%-50%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 0%-45%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Olivine—Mode. 5%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 75-100% by clay mineral(?) or serpentine + talc.

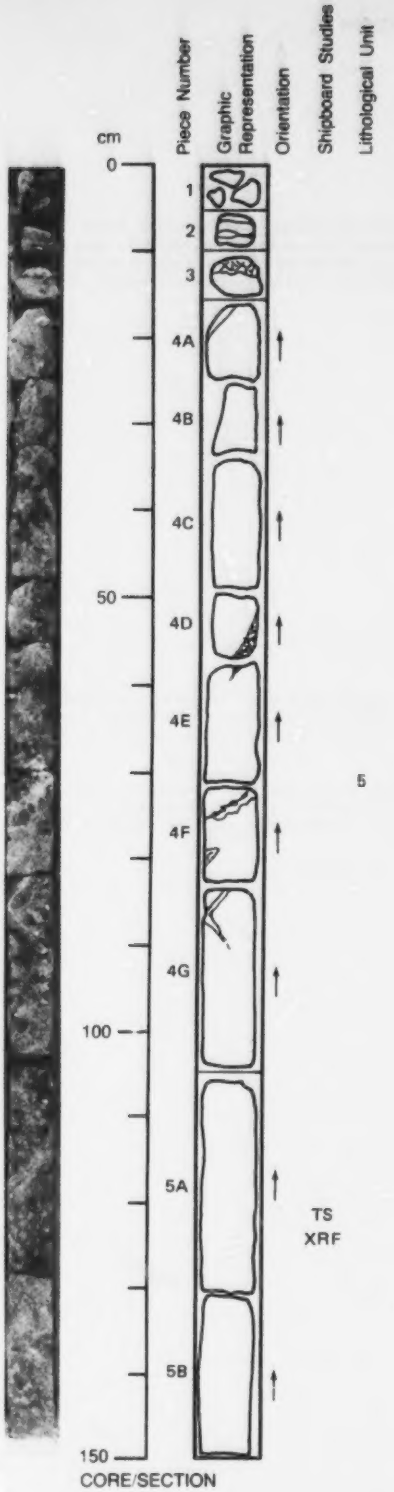
**SECONDARY MINERALOGY:**

Total percent: Not determined.

Texture: Olivine is totally altered in a mesh-like fashion. Mesh defined by dark mineral, probably clay mineral or serpentine; between mesh filled in by white talc. Away from veins primary plagioclase and clinopyroxene almost totally fresh. Near veins clinopyroxene partially replaced by amphibole.

Percent vein material: Not determined.

Vein material: Hematite, talc(?), actinolite, Na-plagioclase, and epidote(?). A 1 cm-wide vein in Piece 3D contains hematite stained plagioclase, pale-green talc(?), and actinolite + sulfides. Thin veins in Piece 1 contain plagioclase, actinolite and epidote(?); this piece 50% altered.



**118-735B-63R-5**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1-5B**

**Olivine Gabbro**

**Pieces 1-5B**

**COLOR:** Gray.
**LAYERING:** Grain size varies from coarse (10-15 mm) to very coarse (10-25 mm).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: Not determined.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: 1% by zoisite, chlorite, and albite.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 3-20 mm.
Crystal shape: Subophitic.
Preferred orientation: None.
Percent replacement: 17% by amphibole.

Olivine—Mode: 3%-10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 40% by talc-tremolite or serpentine.

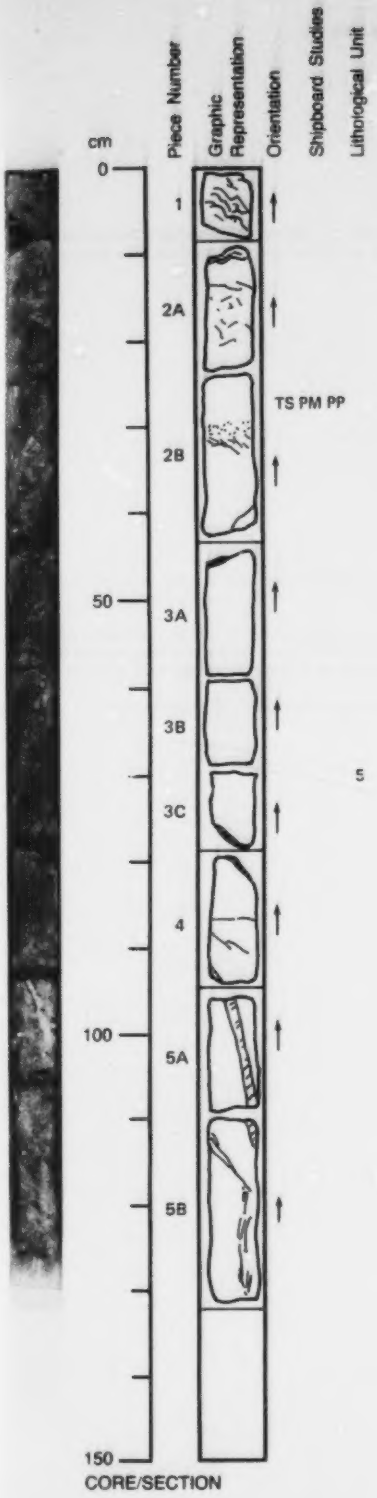
Iron-oxides—Mode: <1%.

Iron-sulphides—Mode: <1%.

**SECONDARY MINERALOGY:**

Total percent: Highly variable.
Texture: Alteration of the gabbro is highly variable depending on proximity to hydrothermal veins. Near the veins the pyroxene is heavily altered to green amphibole, which also occurs filling cracks in the plagioclase, and the olivine is partially to completely replaced by talc-tremolite or serpentine. A few centimeters from the veins the gabbro is markedly fresher with olivine only slightly altered, and only a small (5%) amount of amphibole present. An isolated 2X1 cm talc patch occurs in Piece 3C.
Percent vein material: 3%.
Vein material: Plagioclase, epidote, clinozoisite, actinolite, and iron-sulfides. Hydrothermal veins are a major feature of this section, generally containing plagioclase with accessory epidote, clinozoisite, actinolite, and local enrichments in iron-sulfides. These veins often appear pegmatoidal and may be vuggy, ranging in size from 1 mm to 2 cm thick.
Adjacent to the veins, the gabbro is heavily amphibolitized along a narrow discontinuous selvage.

**COMMENTS:** Equigranular olivine gabbro with a subophitic to ophitic texture with intergranular pyroxene and olivine grown around subhedral plagioclase laths. Olivine may enclose the other minerals. Accessory minerals include iron-oxides and sulfides which occur as fine-grained disseminated inclusions in silicates and intergranular minerals.



## 118-735B-63R-6

**UNIT 5: OLIVINE GABBRO**

**Pieces 1-5B**

**Olivine Gabbro**

**Pieces 1-5B**

**COLOR:** Gray.

**LAYERING:** None well defined. Rather uniformly coarse- to medium-grained, one slightly finer section at 31 cm, one coarse to fine interval at 22-15 cm fining upwards, and a plagioclase-rich layer at 19-20 cm.

**DEFORMATION:** Small shear zone at 4-7 cm (near mylonitic) with some porphyroclastic gabbro on each side. One small shear at 33 cm.

**PRIMARY MINERALOGY:**

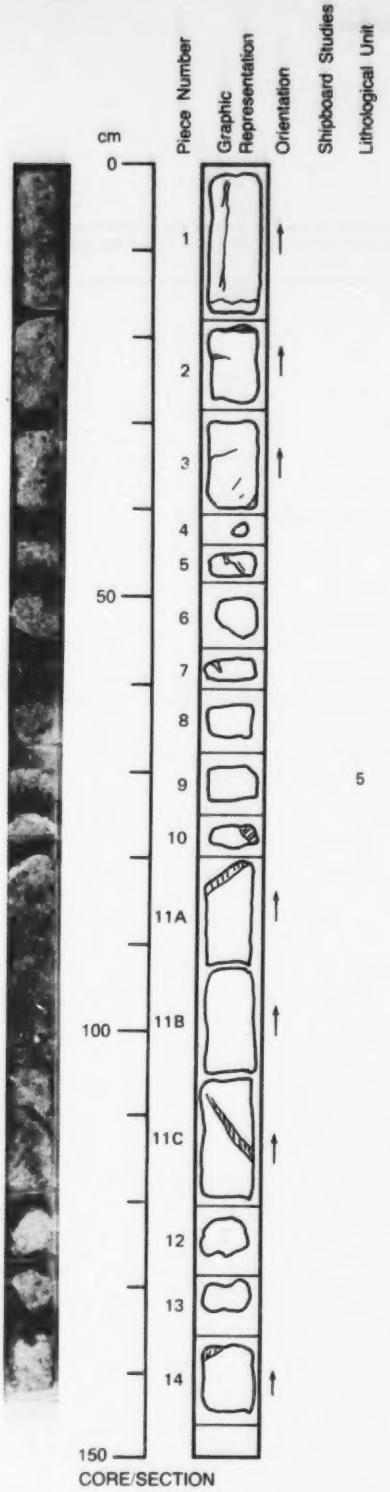
Plagioclase—Mode: 30%-90% locally.
Crystal size: 1-15 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-60%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral, oikocrysts common.
Preferred orientation: Not determined.
Percent replacement: Amphibole after clinopyroxene locally.

Olivine—Mode: 2%-10%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Fresh to altered (iddingsite pseudomorphs).

**SECONDARY MINERALOGY:**

Total percent: Various.
Texture: Clay/hematite after olivine along large veins; pale green amphibole after clinopyroxene in same areas. Thin carbonate rims on top right and bottom left of Piece 4. Rare pyrite. Some amphibolitization is common throughout.
Percent vein material: Not determined.
Vein material: Thick feldspar, epidote, quartz(?) veins (4-10 mm) in Pieces 5A and 5B. Smaller (1 mm) feldspathic veins in Piece 2, amphibole veins in Piece 3A.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CORE/SECTION

**118-735B-63R-7**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-14**

**Olivine Gabbro**

**Pieces 1-14**

**COLOR:** Gray to gray and white.
**LAYERING:** None well defined, some coarse-medium variation but no consistency. Olivine throughout.
**DEFORMATION:** A little brittle deformation (some pyroxene-plagioclase granulation) at 40-75 cm.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 30%-90% locally.
Crystal size: 1-15 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

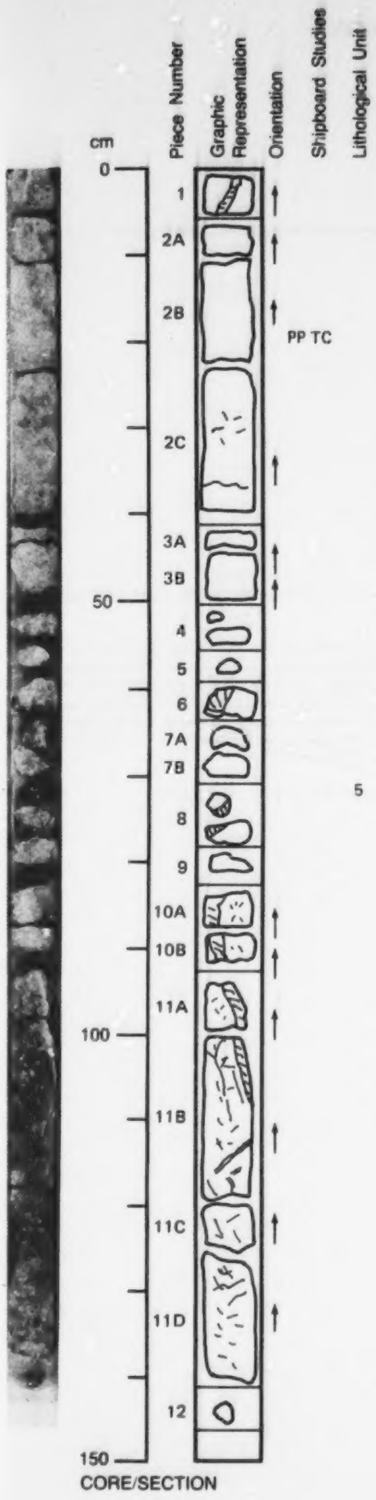
Clinopyroxene—Mode: 20%-60%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral, oikocrysts common.
Preferred orientation: Not determined.
Percent replacement: Amphibole locally.

Olivine—Mode: 2%-10%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Fresh to altered (iddingsite pseudomorphs).

**SECONDARY MINERALOGY:**

Total percent: Various.
Texture: Iddingsite after olivine. Amphibole after clinopyroxene, freshest is Piece 11B, rest are variously altered. No sign of pyrite; amphibolitization and veining may have removed it.
Vein in Piece 10 has a pinkish stain, seems to be associated with small red grains (hematite?).
Percent vein material: Not determined.
Vein material: Large feldspathic epidote-quartz(?) veins at 58, 78, 84, and 112 cm.

**COMMENTS:** Like section 118-735B-63R-6.



118-735B-64R-1

## UNIT 5: OLIVINE GABBRO

**Pieces 1-12**

**Olivine Gabbro**

**Pieces 1-12**

**COLOR:** Gray to gray-green and white where veined.
**LAYERING:** Some very coarse-grained layers, a very coarse- to medium-grained gradation from 130 to 85 cm, possibly a coarse- to medium-grained transition at 30 cm. The very coarse-grained layer has plagioclase and clinopyroxene layers each a single crystal thick. Olivine is distributed throughout. The layering may be locally discontinous. Piece 11C is fine-grained on cored surface, coarse-grained on cut surface.
**DEFORMATION:** Some brecciation from vein intrusion in Pieces 3A-10B.
**PRIMARY MINERALOGY:**

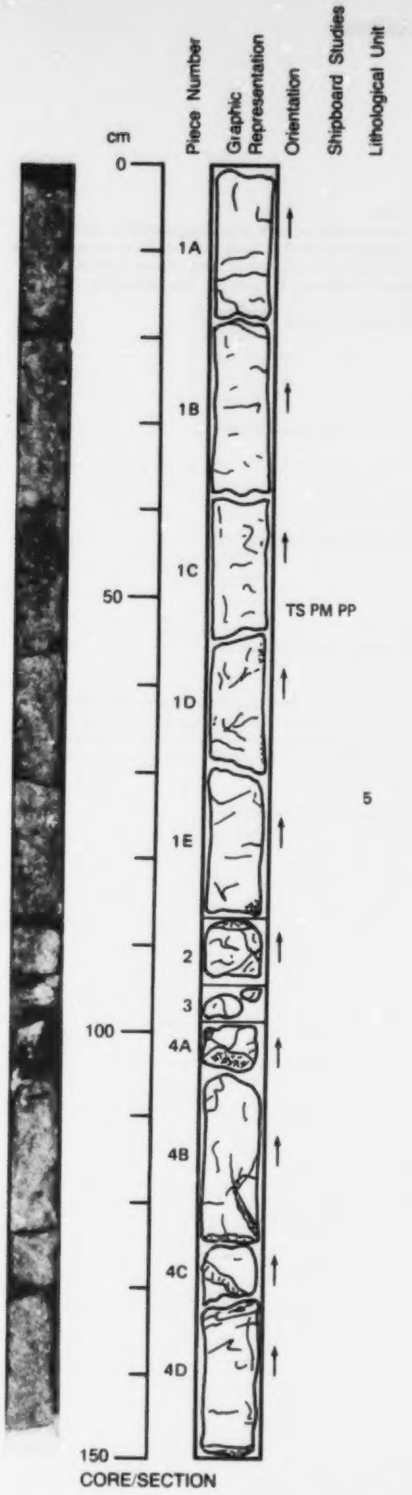
Plagioclase—Mode: 80%-40%.
Crystal size: 2-30 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Some granulation and epidote development.

Clinopyroxene—Mode: 20%-60%.
Crystal size: 2-35 mm.
Crystal shape: Euhedral to anhedral, oikocrysts.
Preferred orientation: Not determined.
Percent replacement: Altered to amphibole, particularly near veins.

Olivine—Mode: 2%-10%.
Crystal size: 2-4 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Usually altered to iddingsitic pseudomorphs.

**SECONDARY MINERALOGY:**

Total percent: Extensive near veins.
Texture: At 40-105 cm the core is cut by a vein network of a feldspar-quartz-actinolite-epidote-hematite assemblage. Piece 5 is a fragment of the vein material. A similar vein cuts Piece 1. Some brecciation and plagioclase granulation in those portions cut by veins. Oxidative alteration of olivine and extensive amphibolitization of clinopyroxene is common near the veins.
Percent vein material: Not determined.
Vein material: Feldspar, quartz, actinolite, epidote, and hematite.



## 118-735B-64R-2

### UNIT 5: OLIVINE GABBRO

**Pieces 1A-4D**

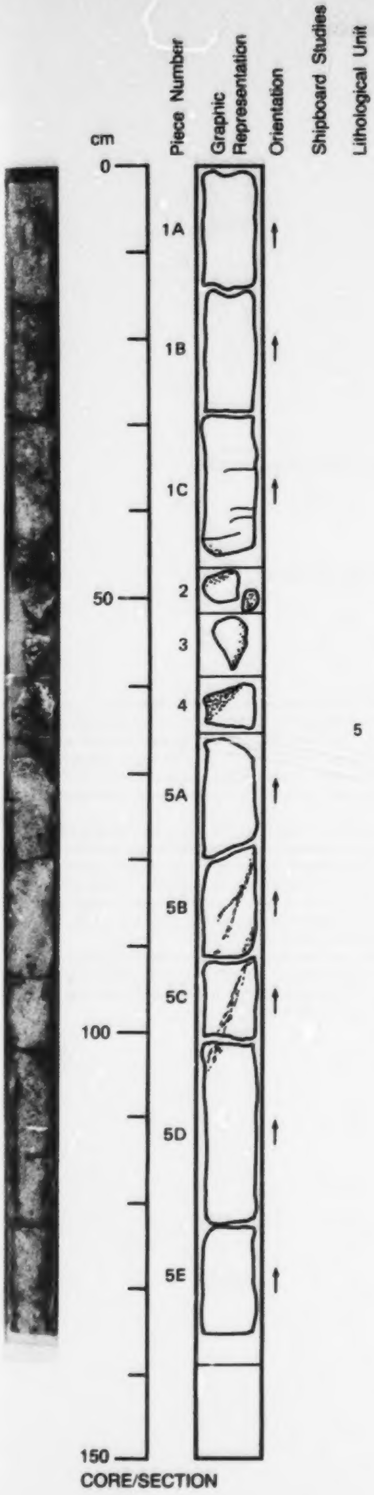
**Olivine Gabbro**

**Pieces 1A-4D**

**COLOR:** Gray with brownish orange spots.
**LAYERING:** Not apparent: gross grain size decreases from top to bottom (maximum 1.5 to <1 cm at base).
**DEFORMATION:** Absent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 0.5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 0.3-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%-40% by talc or by a mixture of iron oxides, clays, and magnetite.
**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Coronitic. Olivine is replaced by talc (10%-40%) or by mixture of orange iron oxides, clays, and magnetite. Clinopyroxene is partially replaced by amphibole (20%). Plagioclase is recrystallized or deformed into granular sub-grains and then cut by amphibole-filled veinlets. Cracks are filled with light green amphiboles; these cracks run into the feldspars. Late formation of iron hydroxides gives yellow to orangish-brown color to feldspars. Other tiny fibrous amphiboles are present in vugs of the vein in Piece 2. Disseminated sulfides in Pieces 1A-1C. Single sulfide grains up to 0.4 mm in Piece 1C.
Percent vein material: Not determined.
Vein material: Plagioclase, epidote, and amphibole in veins 1->2 cm wide.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## 118-735B-64R-3

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-5E**

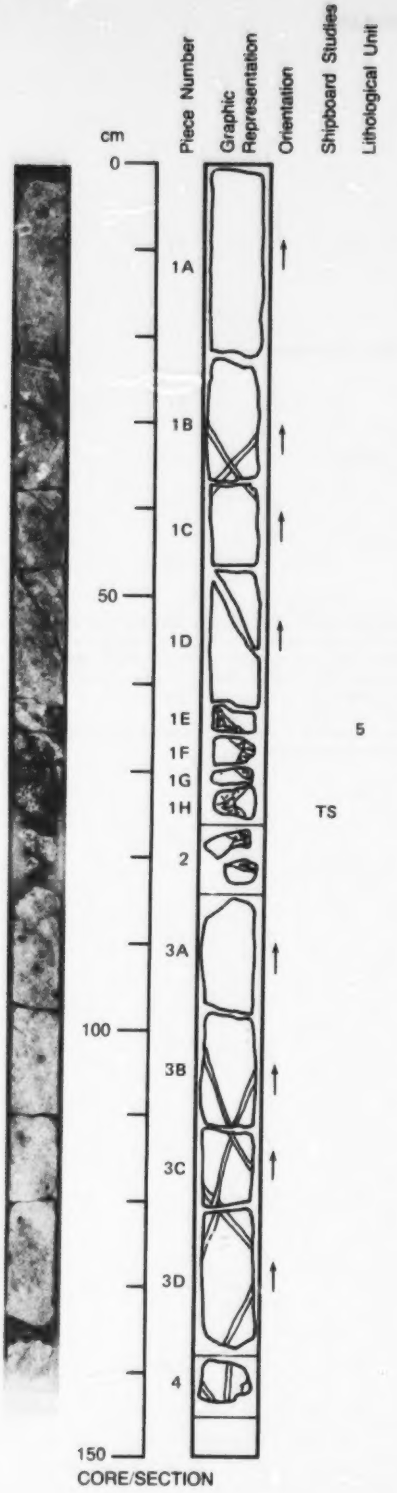
**Olivine Gabbro**

**Pieces 1A-5E**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-50%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: None.
Percent replacement: 10%-100% by milky white feldspar.

Clinopyroxene—Mode: 45%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 10%-100% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 10%-100%.
Texture: Clinopyroxene partially replaced by amphibole. Abundance depends on proximity to veins (i.e., 100% near veins, as little as 10% away from veins). Similarly, plagioclase mostly altered to milky white or hematite-stained feldspar near veins. Olivine altered in mesh-like fashion throughout section, but in intensely veined interval 34-110 cm, olivine is oxidized to orange-brown oxide. Trace of sulfides in Piece 1A.
Percent vein material: Not determined.
Vein material: Plagioclase + actinolite + tremolite + zoisite (rose-colored, prismatic mineral).
**COMMENTS:** Clinopyroxene subophitically enclosing plagioclase.



## 118-735B-64R-4

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-4**

**Olivine Gabbro**

**Pieces 1A-4**

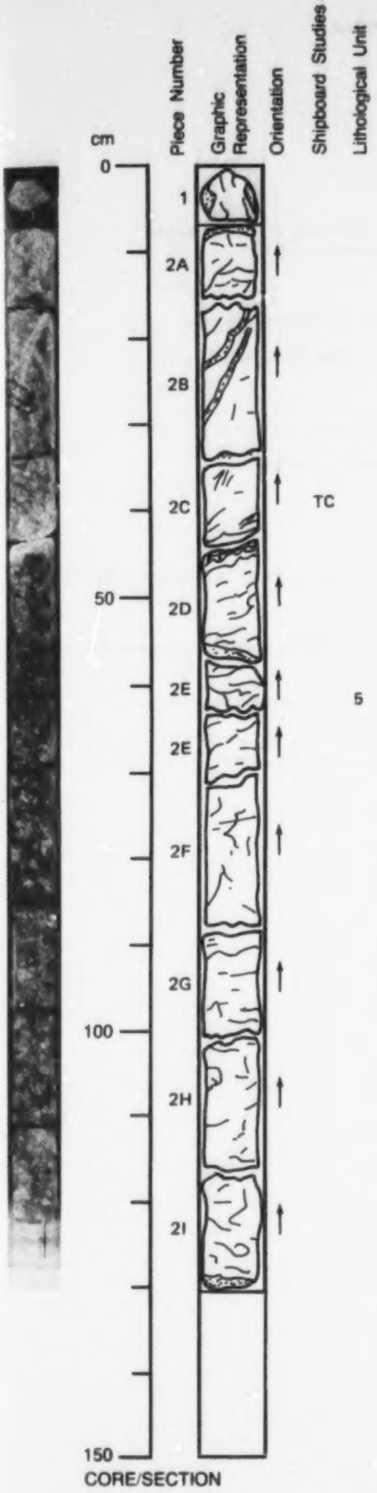
**COLOR:** Gray.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 0.5-45 mm.
Crystal shape: Subhedral laths.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 0.5-4.5 mm.
Crystal shape: Subophitic.
Preferred orientation: None.
Percent replacement: Partial replacement by amphibole near veins.

Olivine—Mode: 5%-10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% by talc-tremolite near veins.

Iron-sulfide—Mode: <1%.

Iron-oxide—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: The alteration of this section of core is complex due to the presence of 3 generations of cross-cutting hydrothermal veins. Near these veins, the alteration of the adjacent gabbro may be extensive; largely consisting of the replacement of olivine by talc-tremolite and the partial replacement of pyroxene by amphibole. The section of the core cut by the last generation of veins, with a yellow-pink carbonate filling, shows extensive oxidative alteration of the olivine, which is converted to or partially replaced by rust red clay or iddingsite.
Percent vein material: 4%.
Vein material: The earliest generation consists of talc-actinolite veins, 2 mm thick, which are inclined about 70° and are cut by the next 2 generations (Pieces 1B, 3A, 3B, and 6D). The second generation also dips about 70° and contains plagioclase, epidote, clinozosite, and actinolite. The second generation also tends to be stained pink, probably by hematitic alteration of iron-sulfides originally in these veins as seen in unaltered veins higher in the core. Locally these veins become relatively massive and irregular (Pieces 1E, 1F, 1G, 1H, and 2), elsewhere they are 2-3 mm thick (Pieces 3A, 3B 3C, 3D, and 3E).
**COMMENTS:** Equigranular gabbro with a subophitic texture. Subhedral plagioclase enclosed in intergranular clinopyroxene and olivine with accessory iron-oxides and sulfides. Grain size varies considerably from the typical 0.5-1.5 cm coarse gabbro to patches of very coarse gabbro where the plagioclase laths reach 4.5 cm in length.



118-735B-65R-1

## UNIT 5: OLIVINE GABBRO

**Pieces 1-2I**

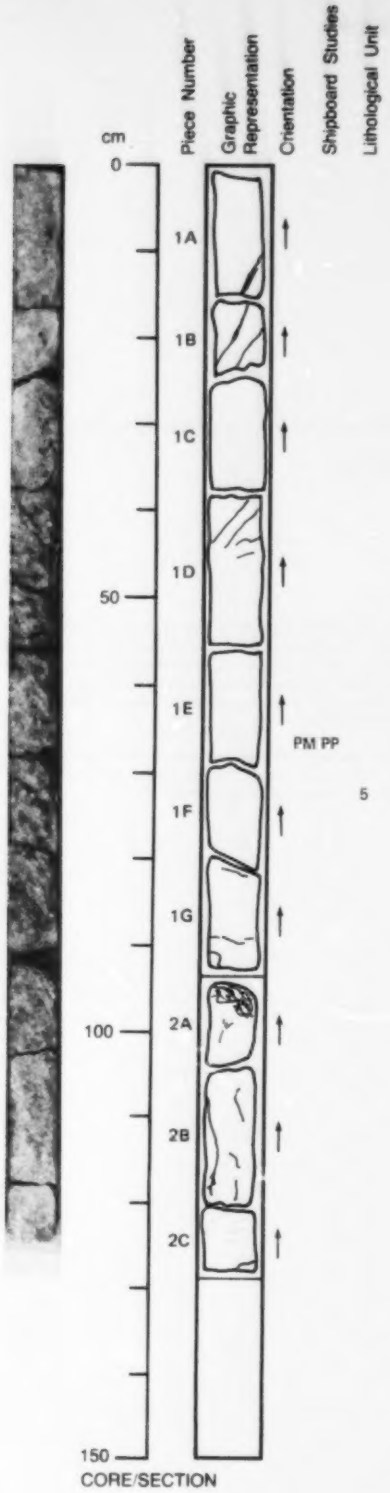
**Olivine Gabbro**

**Pieces 1-2I**

**COLOR:** Gray to greenish gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 2-5 mm.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-15 mm.
Crystal shape: Oikocrystic type, enclosing both olivine and plagioclase but not all the time.
Preferred orientation: None.
Percent replacement: 30%-60% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 1-8 mm.
Crystal shape: Rounded to irregular.
Preferred orientation: None.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: Slight.
Texture: Coronitic, pseudomorphic. Olivine is partly replaced by talc (rims) or by a mixture of orangish brown iron hydroxides and clays. Black veining by magnetite and chlorite define web texture. Clinopyroxene is partly replaced by amphibole (pseudomorphic 30%-60%). Plagioclase is granular on the grain surface. Cracks are filled with amphibole and soapy serpentine and columnar aragonite (HCl test worked; Piece 2E) or talc (blue green). Sulfides are present in Pieces 2A, 2C, 2D, and 2I (pyrite and chalcopyrite).
Percent vein material: Not determined.
Vein material: Plagioclase, amphibole, and epidote. Vein (at least 2-3 cm thick) filled with plagioclase, green amphibole (prismatic), and yellow brown epidote (Pieces 2B and 2C), dips 35°. Vein or discontinous patches of plagioclase and amphibole (dips 70°).


cm
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CORE/SECTION
Piece Number
Graphic Representation
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Shipboard Studies
Lithological Unit
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1B
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1D
1E
1F
1G
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2B
2C
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5

**118-735B-65R-2**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-2C**

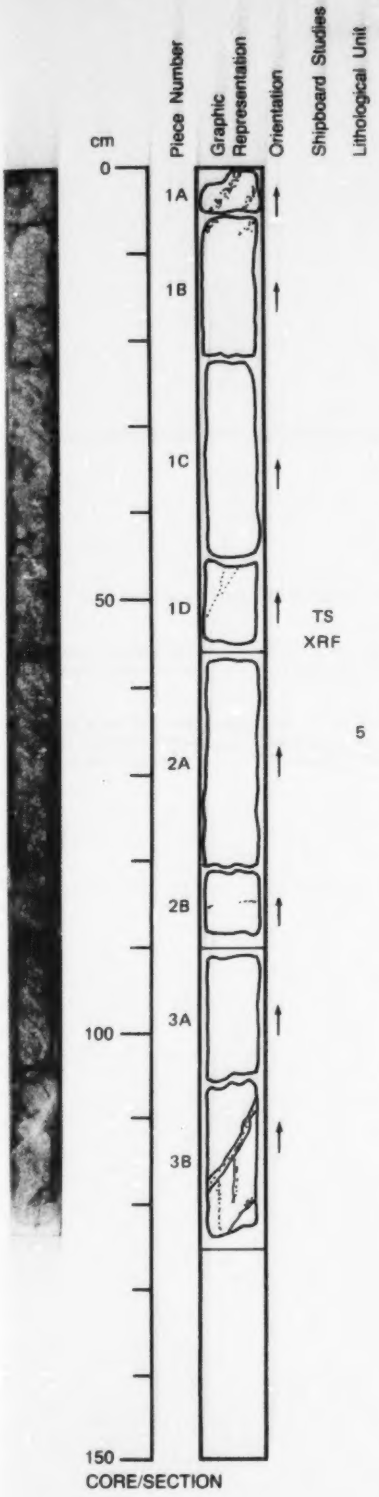
**Olivine Gabbro**

**Pieces 1A-2C**

**COLOR:** Gray to green-gray where altered.
**LAYERING:** Some coarse to fine variation in top; rest is medium to coarse-grained.
**DEFORMATION:** Small amphibolitized shear zone at top of Piece 2A.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-55%.
Crystal size: 2-20 mm.
Crystal shape: Euhedral (small ones in clinopyroxene) to anhedral.
Preferred orientation: Not determined.
Percent replacement: Some albitization in Pieces 2B and 2C.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-20 mm.
Crystal shape: Anhedral to subhedral, some oikocrysts.
Preferred orientation: Not determined.
Percent replacement: Some amphibolitization toward bottom.

Olivine—Mode: 5%-15%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to blackish amphibole, whitish talc alteration in Piece 2C, oxidative pseudomorphs in Pieces 2A and 2B.
**SECONDARY MINERALOGY:**
Total percent: Various.
Texture: Olivine pseudomorphed as noted, amphibolitization of clinopyroxene, some albite after plagioclase in Pieces 2B and 2C.
Percent vein material: Not determined.
Vein material: Small (1-2 mm) feldspathic veins in Pieces 1A, 1B, and 2.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Graphic Representation
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Shipboard Studies
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3A
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XRF
5
CORE/SECTION

## 118-735B-65R-3

### UNIT 5: OLIVINE GABBRO

**Pieces 1A-3B**

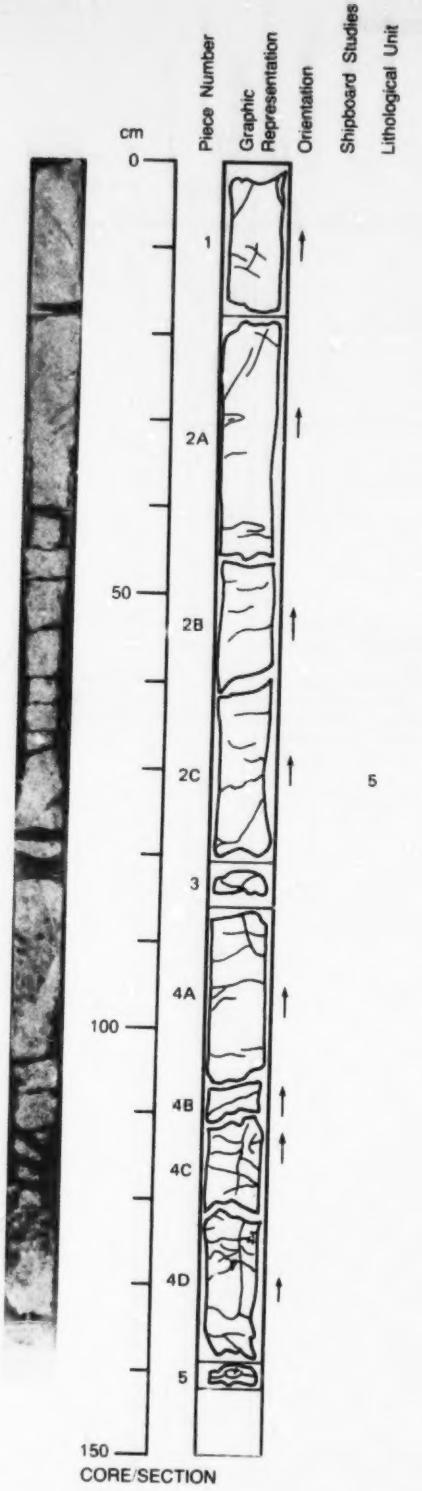
**Olivine Gabbro**

**Pieces 1A-3B**

**COLOR:** Gray.
**LAYERING:** Possible primary layering defined by variation in grain size between Pieces 3A and 3B.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 40%.
Crystal size: 5-40 mm.
Crystal shape: Anhedral to subhedral; subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: <1%.

Olivine—Mode: 5%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%-10%.
**SECONDARY MINERALOGY:**
Total percent: 3%-5%.
Texture: Grain boundaries lined by actinolite, as are very thin fractures in Piece 1D. This is the main form of alteration in this section and constitutes 2%-3% of rock.
Percent vein material: Not determined.
Vein material: Major veins 1 mm wide in Piece 1A and 10 mm wide in Piece 3B. Vein in Piece 1A has soft white mineral (probably talc) + actinolite + zoisite at top of piece. Piece 3B veins are plagioclase + very fine-grained green amphibole (actinolite). Orangish oxidation on portion of Piece 1A is separate from plagioclase + actinolite vein.



**118-735B-66R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-5**

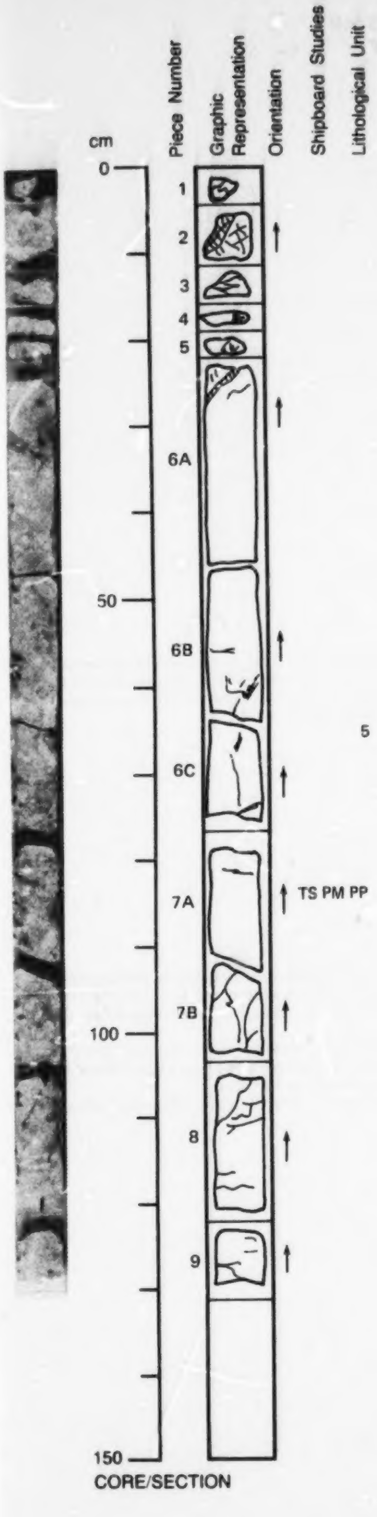
**Olivine Gabbro**

**Pieces 1-5**

**COLOR:** Gray with orangish-brown spots.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 1-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral to subhedral, of oikocrystic type enclosing plagioclase (subophitic texture) and rounded olivine.
Preferred orientation: None.
Percent replacement: Slight

Olivine—Mode: 10%-15%.
Crystal size: 2.6 mm.
Crystal shape: Rounded to irregular.
Preferred orientation: None.
Percent replacement: 10%-100% by iron hydroxides and clays, talc and magnetite.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Olivine is altered to a mixture of iron hydroxides and clays or mixture of talc + magnetite. They are fresh in Pieces 1, 2A and 2B (less than 10% replacement). Clinopyroxene partly replaced by green amphibole.
Percent vein material: Not determined.
Vein material: Plagioclase, epidote, and actinolite. Vein (base of Pieces 4D and 5) filled with plagioclase, epidote (green pistacite), yellow-brown zoisite, and fibrous to acicular actinolite. Cracks and veinlets filled with amphibole, plagioclase, clay, and carbonate (Piece 3).



**118-735B-66R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-9**

**Olivine Gabbro**

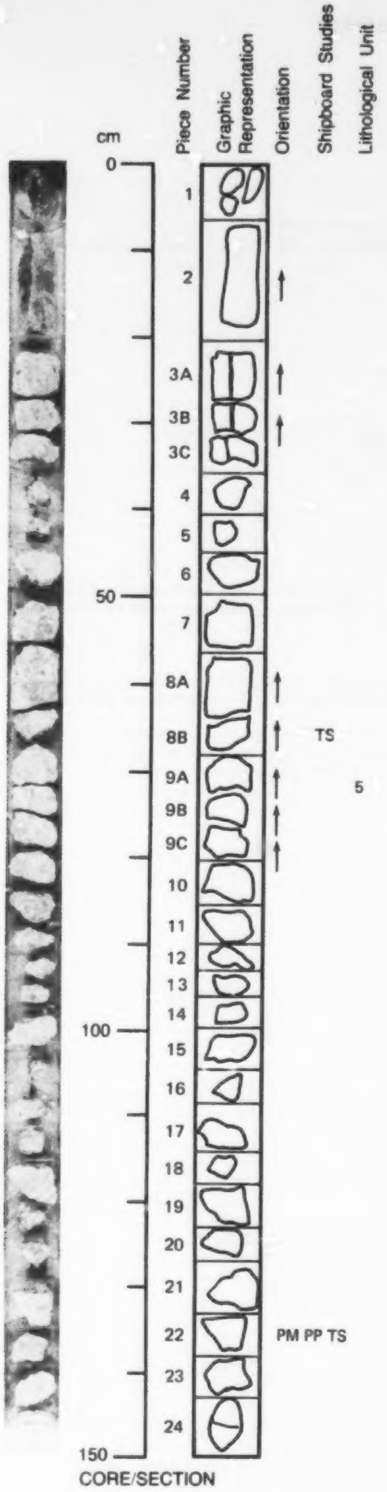
**Pieces 1-9**

**COLOR:** Gray; white-green gray where altered.
**LAYERING:** None clearly defined. A very coarse interval at 24-23 cm.
**DEFORMATION:** Some brecciation in veined zone 0-26 cm, a lot of cross-cutting brittle fractures from 59 cm downwards.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 2-20 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 4-25 mm.
Crystal shape: Anhedral, largely interstitial.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 2%-10%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Variously altered at 30-59 cm, black-green veined alteration patches. In rest of core olivine has undergone an oxidative alteration (iddingsite) usually adjacent to the fractures.
**SECONDARY MINERALOGY:**
Total percent: Up to 40% in top 5 pieces.
Texture: Olivine as noted; in oxidative zones also common amphibolitization of clincpyroxene. Also amphibole along fractures. Sometimes feldspathic veins associated with fractures too.
Percent vein material: Not determined.
Vein material: Top 5 pieces are veined (as is top of Piece 6A) by 2-10 mm wide veins of feldspar-actinolite-epidote-quartz; veins are dominated by feldspar + epidote, and lack carbonate. Some smaller such veins occur in lower part of section (21 mm wide).

**COMMENTS:** No pyrite identified in section.



**118-735B-66R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces: 1-24**

### Olivine Gabbro

**Pieces 1-3B**

**COLOR:** Gray.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: Medium to coarse.
Crystal shape: Anhedral granular.
Preferred orientation: None.
Percent replacement: Variable.

Clinopyroxene—Mode: 35%.
Crystal size: Medium to coarse.
Crystal shape: Subophitic.
Preferred orientation: None.
Percent replacement: Variable.

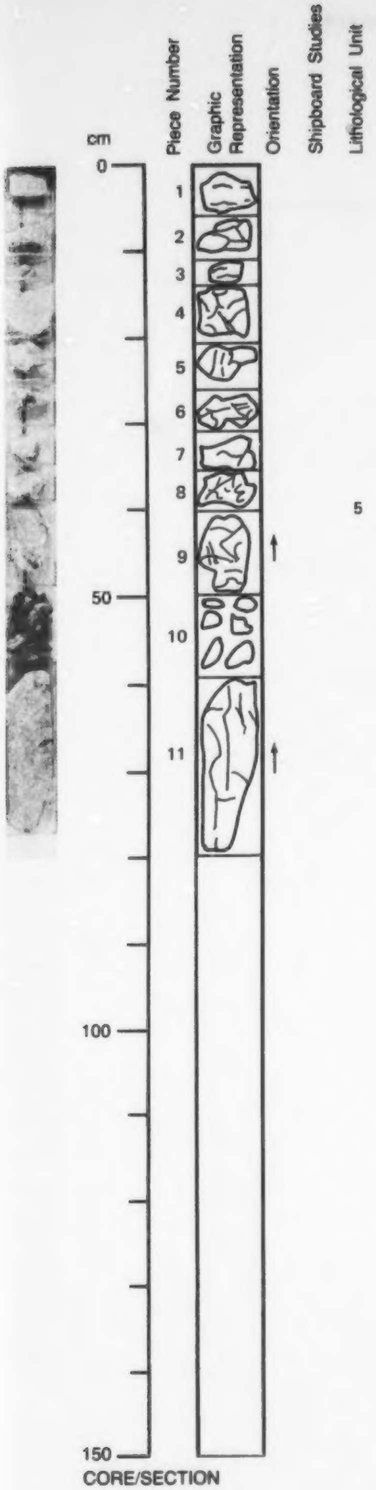
Olivine—Mode: 10%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Variable.

Opaques—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Variable.
Texture: Near the vein the alteration is extensive, giving the rock a distinct greenish cast. Nonetheless, much of the gabbro appears relatively fresh with the principle sign of alteration being patches of prehnite(?) replacing plagioclase and rust brown oxidation of primary olivine. A large fracture surface on Piece 2 may have chlorite on it.
Percent vein material: Not determined.
Vein material: Epidote, actinolite, and prehnite(?).

### Epidosized Gabbro Breccia

**Pieces 3C-24**

**COLOR:** White with green cast and gray.
**LAYERING:** None.
**DEFORMATION:** Autoclastic breccia.
**PRIMARY MINERALOGY:** Similar to olivine gabbro above.
**SECONDARY MINERALOGY:**
Total percent: 80%-90%.
Texture: Angular clasts of altered gabbro criss-crossed by epidote-rich (pistacite) veins with prehnite and/or tremolite. Plagioclase in gabbro clasts appears altered to prehnite locally while olivine is oxidized. Pyroxene appears partially replaced or pseudomorphed by actinolite.
Percent vein material: Not determined.
Vein material: Locally the veins contain carbonate, which can occur as aragonite(?) crystals in small vugs. Matrix in veins other than epidote and actinolite is likely to be a mixture of plagioclase (albite?) and other calc-silicates (talc-tremolite, etc.).
**COMMENTS:** This whole section looks like a hydrothermal stockwork cross-cutting and working its way up through the gabbro.



## 118-735B-66R-4

### UNIT 5: OLIVINE GABBRO

**Pieces 1-11**

### Hydrothermally Deformed Olivine Gabbro

**Pieces 1-8 and 10**

**COLOR:** Yellow green.
**LAYERING:** Not present.
**DEFORMATION:** Foliation developed in Pieces 4 and 8 and brecciation in other pieces.
**PRIMARY MINERALOGY:** The rock was a gabbro composed of plagioclase, clinopyroxene, and maybe olivine. No primary phases are preserved.
**SECONDARY MINERALOGY:**
Total percent: 100%.
Texture: Plagioclase (albite?), rhombohedral calcite, epidote (green: pistacite, rose: zoisite), amphibole (after clinopyroxene), white fibrous tremolite, and some vitreous grains that are probably quartz.
Percent vein material: Not determined.
Vein material: Not determined.

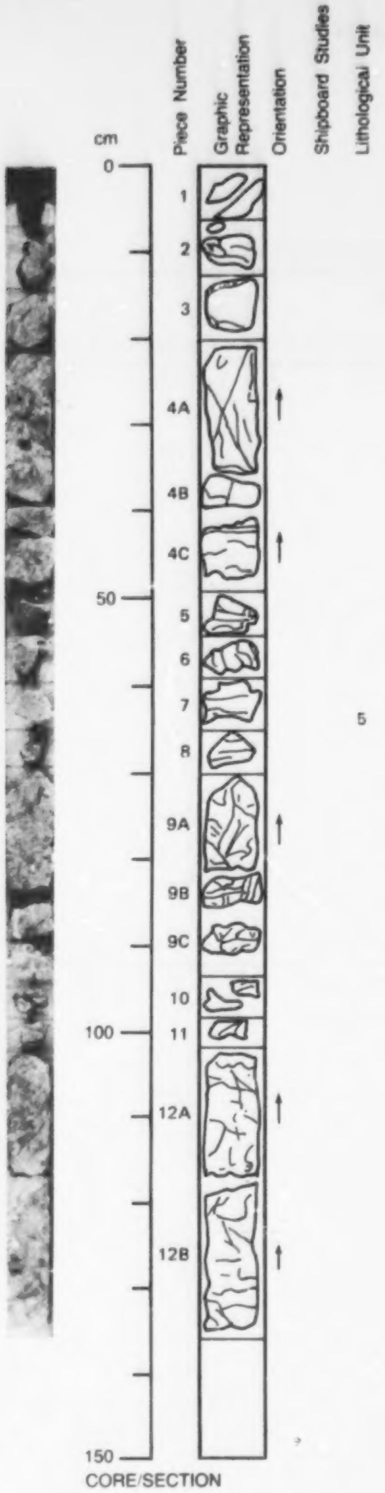
### Olivine Gabbro

**Pieces 9, 11, and fragments of Piece 10**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 35%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: 40% by epidote.

Clinopyroxene—Mode: 60%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 40% by amphibole.

Olivine—Mode: 5%.
Crystal size: 1-5 mm.
Crystal shape: Irregular, lense-shaped.
Preferred orientation: None.
Percent replacement: 60-70% by iron hydroxides, clays, and talc.
**SECONDARY MINERALOGY:**
Total percent: Approximately 40%.
Texture: Pseudomorphic. Olivine replaced by mixture of orange-brown iron hydroxides and clays (+ magnetite) and by dark talc (60-70%). Clinopyroxene is replaced by amphibole (40%). Plagioclase is cut by amphibole veinlets and partly replaced by epidote (yellow color; 40%).
Percent vein material: Not determined.
Vein material: Veins filled by yellow-green amphibole + epidote.


cm
Piece Number
Graphic Representation
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Shipboard Studies
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12A
12B
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CORE/SECTION

**118-735B-67R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-12B**

### Hydrothermally Altered Gabbro

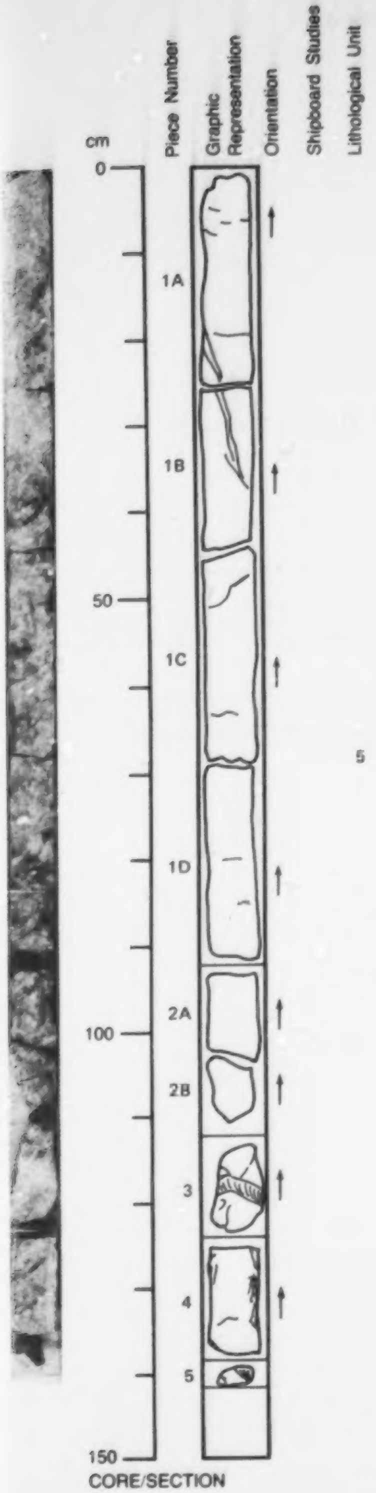
**Pieces 1-12B**

**COLOR:** Irregular patches of dark green to yellow green and white colors.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 35%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 60%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 40% by amphibole.

Olivine—Mode: 5%.
Crystal size: 1-5 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: 60%-70% by iron hydroxides, clays, and talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Coronitic.
Percent vein material: Not determined.
Vein material: Amphibole and epidote.
**COMMENTS:** For comments see Section 118-735B-66R-4.

## 118-735B-67R-2



### UNIT 5: OLIVINE GABBRO

**Pieces 1A-5**

**Olivine Gabbro**

**Pieces 1A-5**

**COLOR:** Gray.

**LAYERING:** No clear graded layers but two very coarse-grained layers 3 cm thick at 79-83 cm; and 9.5 cm thick at 121-130 cm containing clinopyroxene oikocrysts with included 2 cm euhedral plagioclase. Most of core is coarse-grained. Olivine distributed throughout. A plagioclase rich zone below large clinopyroxene.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

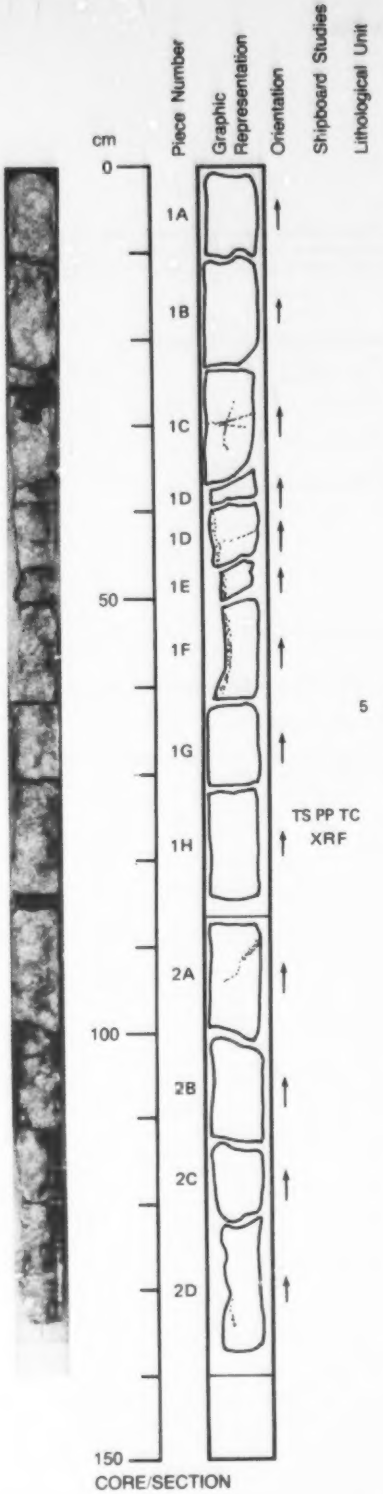
Plagioclase—Mode: 40%-60%, commonly partially enclosed in clinopyroxene.
Crystal size: 2-20 mm.
Crystal shape: Euhedral in clinopyroxene to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 5-20 mm, rarely to 90 mm.
Crystal shape: Anhedral, interstitial to poikilitic; rarely subhedral.
Preferred orientation: Not determined.
Percent replacement: Rare.

Olivine—Mode: 2%-10%.
Crystal size: 2-12 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Altered to talc, tremolite and chlorite(?).

**SECONDARY MINERALOGY:**

Total percent: Up to 5%.
Texture: Olivine replaced by talc, tremolite, and chlorite(?). Talc pseudomorphs by vein in Piece 3.
Clinoproxene rarely amphibolitized, usually adjacent to veins.
Percent vein material: 5%.
Vein material: Large felspathic-actinolite-epidote vein in Piece 3, similar veining on right side of Pieces 4 and 5. Most of green in these veins is actinolite.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Orientation
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CORE/SECTION

**118-735B-67R-3**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-2D**

**Olivine Gabbro**

**Pieces 1A-2D**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

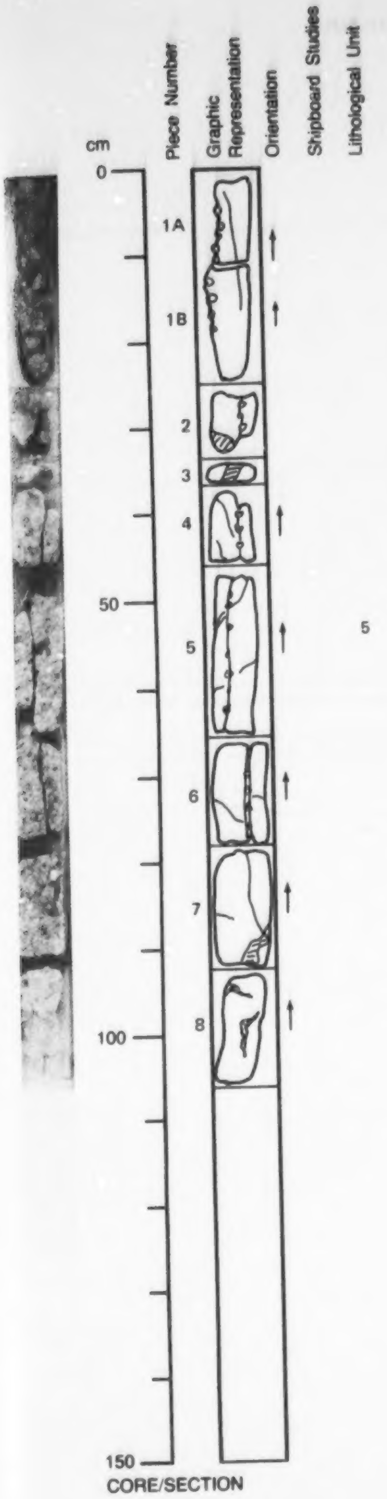
Plagioclase—Mode: 55%.
Crystal size: 8-25 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 40%.
Crystal size: 5-25 mm.
Crystal shape: Subhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 10-25% by amphibole.

Olivine—Mode: 5%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 100% from 0-66 cm, <1%-2% from 66 cm to bottom.

**SECONDARY MINERALOGY:**

Total percent: <5%. This section extremely fresh in general.
Texture: Olivine is totally altered to black mineral in mesh-work fashion from 0-66 cm. Below, olivine is very fresh; <1-2% alteration by amphibole along grain boundaries. Plagioclase unaltered.
Percent vein material: Not determined.
Vein material: Most veins are thin and filled by white minerals, (plagioclase or prehnite). Outer surface of Pieces 1C, 1D, 1E, and 1F coated by a bluish green mineral plus a coating of orange-brown oxidation, i.e., probably a greenish talc + iron-oxyhydroxides.



118-735B-87R-4

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-8**

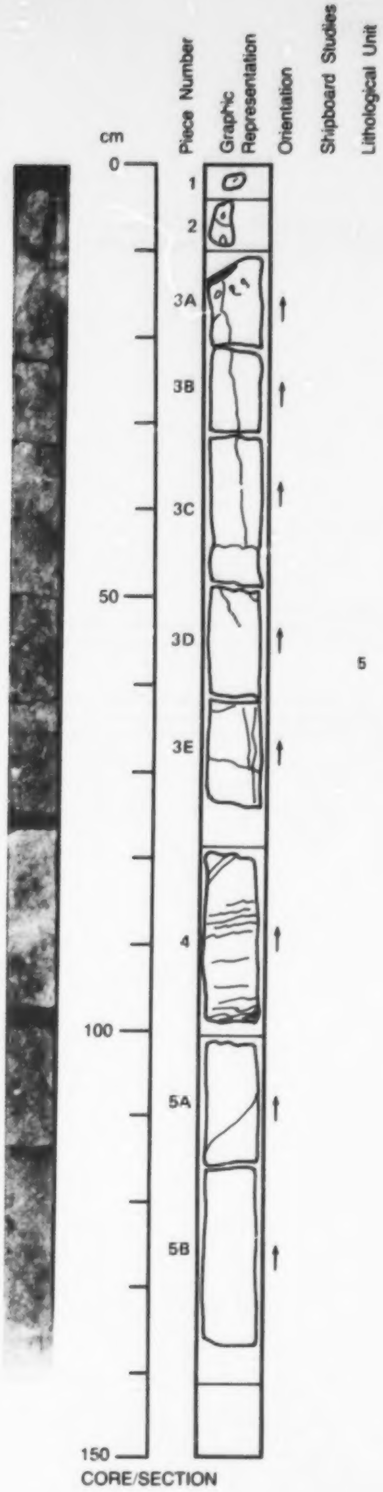
**Olivine-Bearing and Olivine Gabbro**

**Pieces 1A-8**

**COLOR:** Gray with white veins and red patches.
**LAYERING:** Pieces 4, 5, 6, and 7 have more olivine (about >5%). No magmatic lamination.
**DEFORMATION:** No plastic deformation; slight breciation due to veining in Pieces 7 and 8.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 1-4 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 1-4 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 2%-5%.
Crystal size: 1-2 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 15%->70% close to the amphibole veins.
Texture: The olivine is 60%-70% oxidized, the clinopyroxene is amphibolitized. The extent of this amphibolitization is maximum close to the amphibole veins, and reaches 100% in parts of Piece 8.
Percent vein material: 1%-5%.
Vein material: There are 3 types of veins (1) 1-10 mm-thick amphibole ± epidote ± quartz veins (hatched pattern), (2) thin white veins (thin lines), and (3) carbonate-coated open fracture (open dots). The cross-cutting relationships indicate the following chronology: (1), (2), and (3).
**COMMENTS:** Grain size: 1-2 cm, up to 4 cm in Piece 8.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CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1
2
3A
3B
3C
3D
3E
4
5A
5B
5

118-735B-68R-1

**UNIT 5: OLIVINE-GABBRO**

**Pieces 1-4B**

**Olivine-Bearing Gabbro**

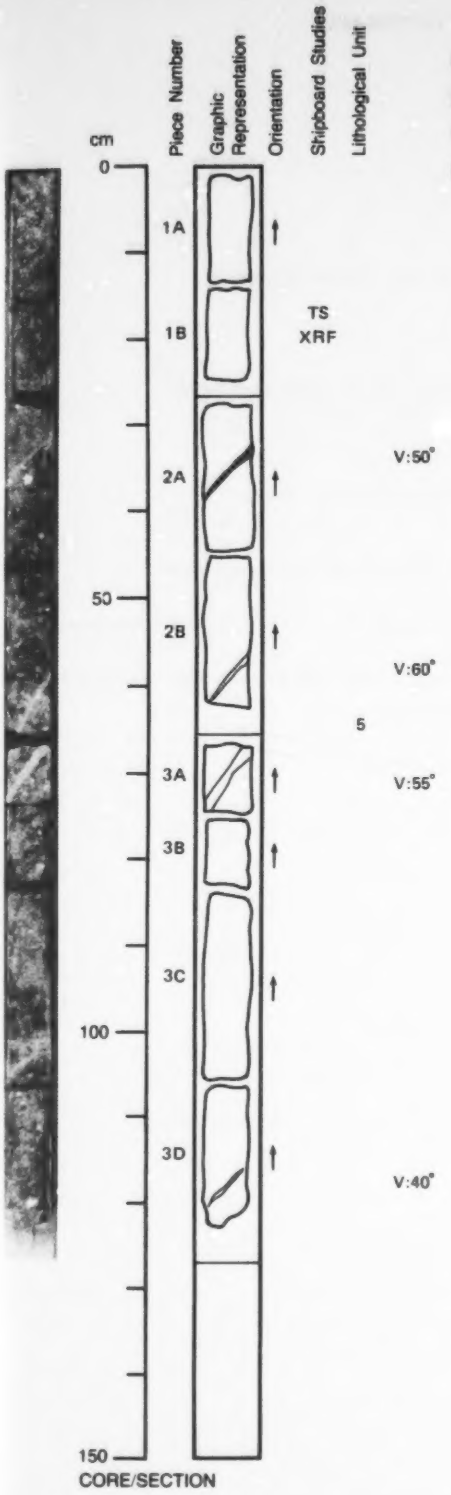
**Pieces 1-4B**

**COLOR:** Gray.
**LAYERING:** None apparent; minor grain size variations, in general, coarse-grained (1-2 cm). Olivine is slightly enriched in Piece 5B.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 0.5-3 cm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: <2%-10%, average 3%.
Crystal size: 0.4-2 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Olivine in certain intervals completely altered to brownish, sometimes black alteration products. Amphibole replaces clinopyroxene along grain boundaries. Sulfide dissemination.
Percent vein material: Not determined.
Vein material: Carbonate vein on very top of Piece 3A. Thick vein (up to 3 cm across) with greenish and white minerals in Piece 4 (at about 85-90 cm). Two "white" veins on top and bottom of Piece 4.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1A
1B
2A
2B
3A
3B
3C
3D
TS
XRF
5
V:50°
V:60°
V:55°
V:40°

118-735B-88R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3D**

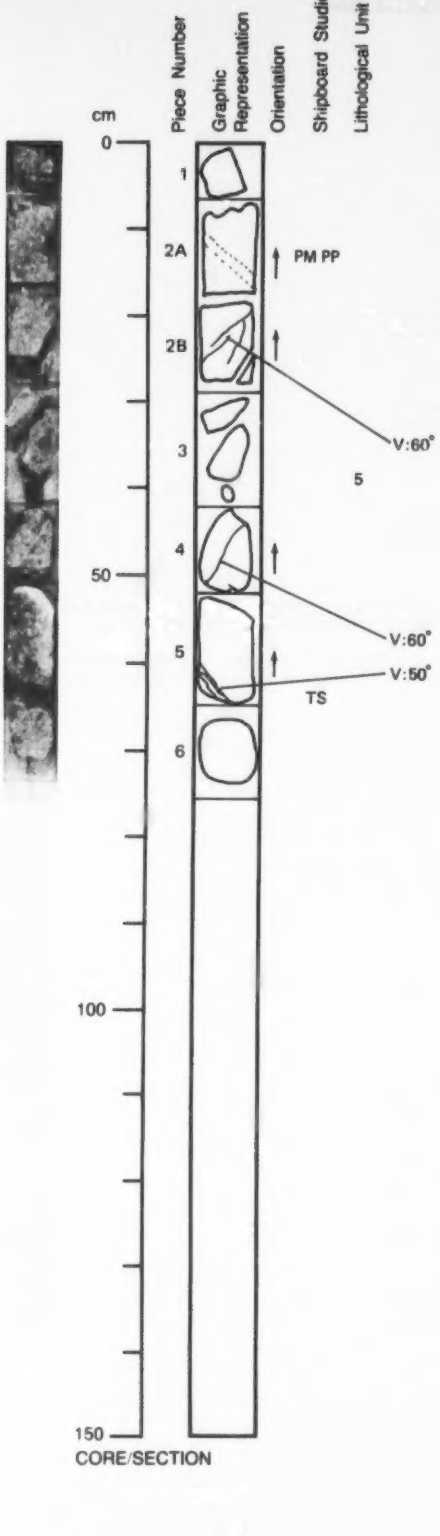
**Olivine Gabbro**

**Pieces 1A-3D**

**COLOR:** Gray to greenish near veins.
**LAYERING:** None apparent.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-45%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 2%-10%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Clinopyroxene partly replaced by green amphibole. Olivine partly replaced by magnetite + tremolite + talc (chlorite rims when bordering plagioclase).
Percent vein material: Not determined.
Vein material: Veins, 0.5 12 mm thick, filled with plagioclase + epidote + sphene (rare) + green amphibole. Alteration halo around 12-mm-wide vein in Piece 3A extends 30 mm into host gabbro.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2A
2B
3
4
5
6
PM PP
TS
V:60°
V:60°
V:50°
5
CORE/SECTION

118-735B-68R-3

## UNIT 5: OLIVINE GABBRO

**Pieces 1-6**

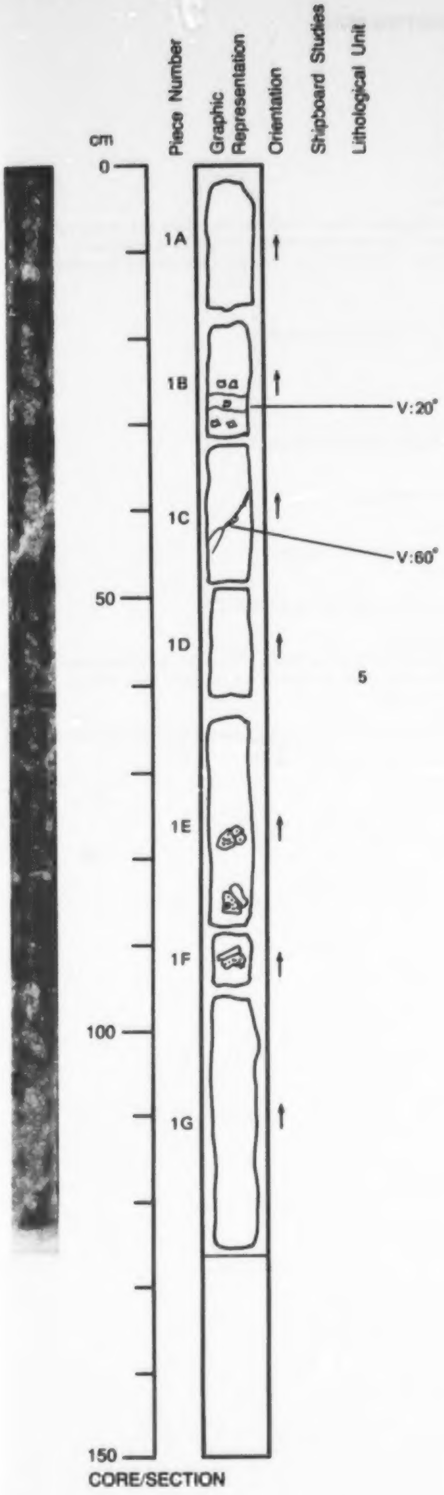
**Olivine-Bearing Gabbro**

**Pieces 1-6**

**COLOR:** Greenish gray.
**LAYERING:** None apparent.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Pieces 1-2B: 65%, Pieces 3-6: 50%-60%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: Pieces 1-2B: 20%-30%, Pieces 3-6: 30%-25%.
Crystal size: 4-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 15-20% by amphibole.

Olivine—Mode: Pieces 1-2B: 5%-10%, Pieces 3-6: 3%-5%.
Crystal size: 5 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 4% by amphibole or clay, replacement pervasive.
**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: Amphibole replaces clinopyroxene up to 15%-20%. Olivine is replaced by chlorite or by clay or by amphibole (4%).
Percent vein material: Abundant.
Vein material: Prehnite, amphibole, and albite veins. Thickness ranges 1-15 mm inclining 50-60° in Pieces 2B, 4, and 5.
**COMMENTS:** Fine-grained ophitic band in Piece 2A.



**118-735B-69R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1G**

**Olivine Gabbro**

**Pieces 1A-1G**

**COLOR:** Gray.

**LAYERING:** Size grading, coarsening downwards from Piece 1B (average sizes of plagioclase and clinopyroxene: 10 mm), to Pieces 1E-G (average sizes of plagioclase and clinopyroxene: 35 mm). Bottom of Piece 1G is finer-grained than top of Piece 1G. Size grading occurs over approximately 80 cm interval.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

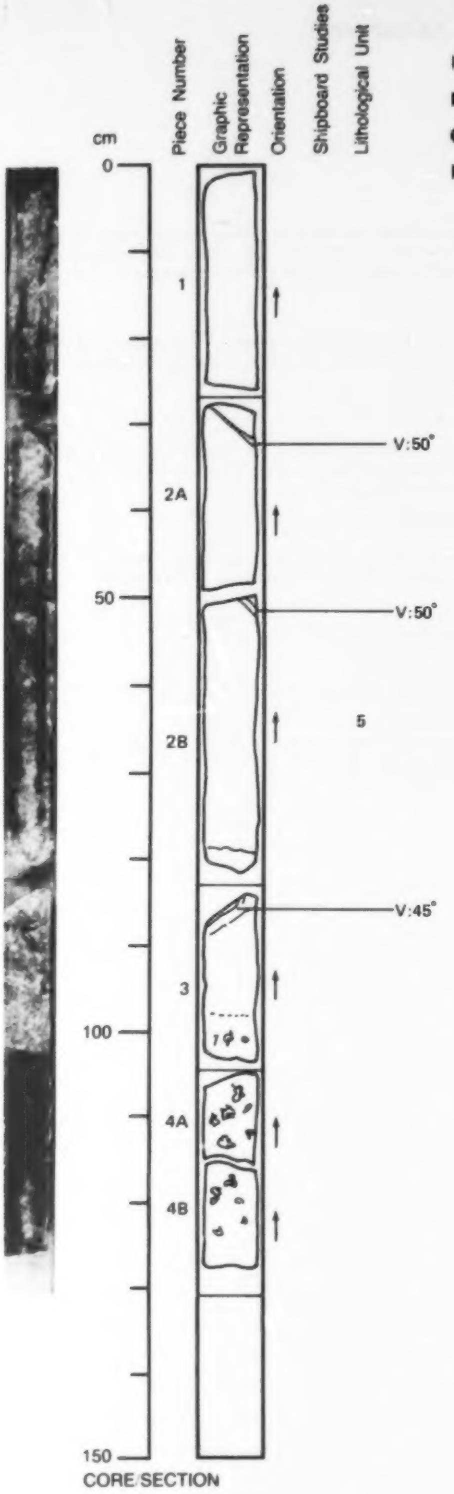
Plagioclase—Mode: 50%-60% (medium-grained interval), 50%-55% (coarse-grained interval).
Crystal size: 7-15 mm (medium-grained interval), 10-40 mm (coarse-grained interval).
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40% (medium-grained interval), 40%-45% (coarse-grained interval).
Crystal size: 5-15 mm (medium-grained interval), 15-50 mm (coarse-grained interval).
Crystal shape: Subhedral, oikocrystic (Piece 1G).
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10% (medium-grained interval), 5% (coarse-grained interval).
Crystal size: 3-6 mm (medium-grained interval), 5-15 mm (coarse-grained interval).
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Green amphibole replacing clinopyroxene, olivine partly replaced by tremolite with chloritic rims near plagioclase.
Percent vein material: Not determined.
Vein material: Veins in Pieces 1B and 1C are 1-3 mm thick, filled with plagioclase + epidote + amphibole with minor amounts of sphene and pyrite. Veins in Piece 1B dip at 20° in opposite direction to those in Piece 1C which dip at 60°.



**118-735B-69R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-4B**

**Olivine Gabbro**

**Pieces 1-4B**

**COLOR:** Gray.
**LAYERING:** Grain size variation suggests layering. Pieces 1-3 are coarse-grained and locally ophitic, Pieces 3-4 are fine-grained ophitic. The most characteristic difference is grainsize of plagioclase; 10-30 mm vs. 5-20 mm. Olivine is rich in Piece 2B. Layer contact is gradational.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: 5-20 mm coarse-grained, 10-30 mm fine-grained.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: None.

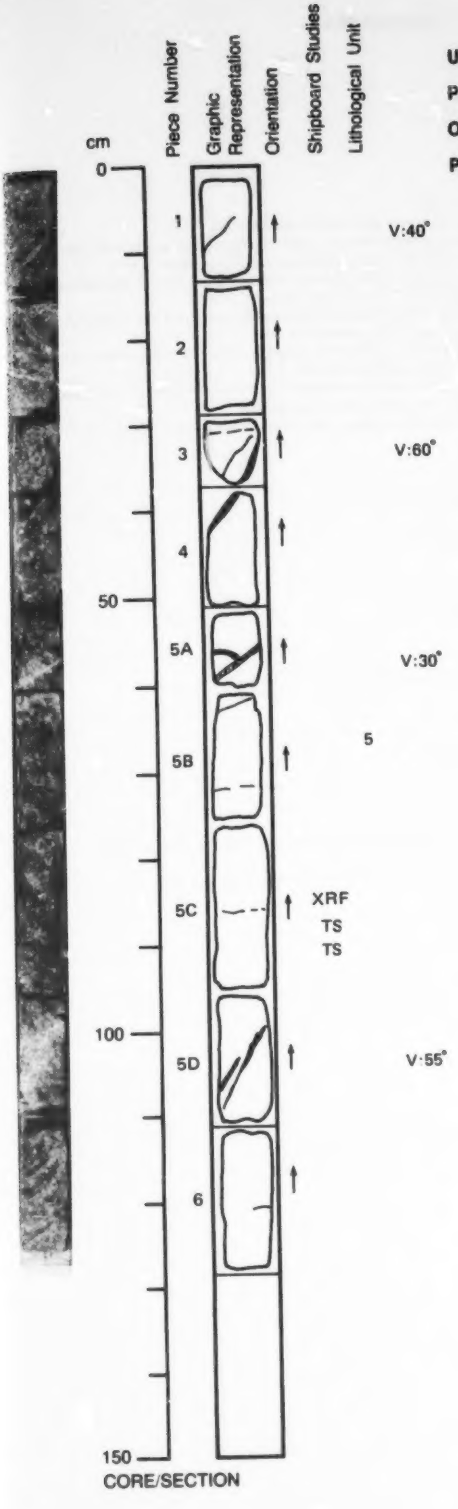
Clinopyroxene—Mode: 20%-30%.
Crystal size: 5-20 mm coarse-grained, 3-20 mm fine-grained.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%-20% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 5-15 mm coarse-grained, 5 mm fine-grained.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Various, none-extensive by amphibole.

**SECONDARY MINERALOGY:**

Total percent: Almost none, 20% locally.
Texture: Amphibole replacing clinopyroxene is less than a few percent excepting altered portion in Pieces 2B and 3, where its mode is up to 20%. In this altered zone olivine is also severely altered to tremolite or chlorite(?).
Percent vein material: Abundant.
Vein material: In vein present in Piece 2A, epidote occupies the center of the vein and is jacketed by white albite.

## 118-735B-69R-3


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5A
5B
5C
5D
6
V:40°
V:60°
V:30°
V:55°
XRF
TS
TS
5
CORE/SECTION

**UNIT 5: OLIVINE GABBRO**

**Pieces 1-6**

**Olivine Gabbro**

**Pieces 1-6**

**COLOR:** Gray.

**LAYERING:** Faint grain size variation: fine-grained from 0 to 30 cm, medium-grained from 30 to 70 cm, fine-grained below 70 cm. Faint modal variations: olivine-rich band in Piece 5B. No magmatic lamination.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

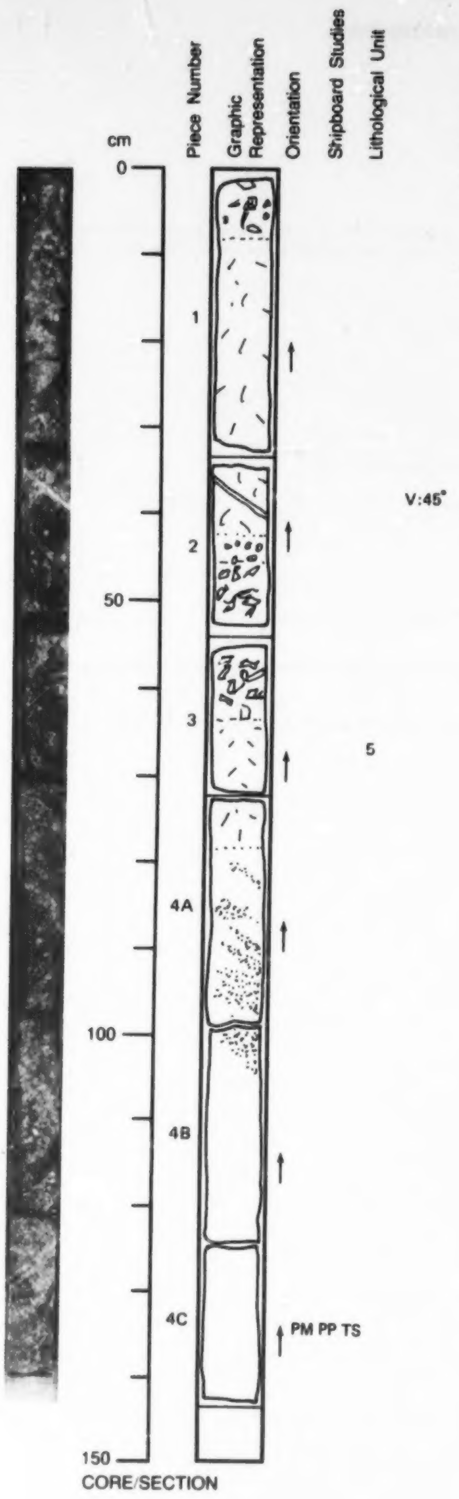
Plagioclase—Mode: 50%-60%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Fresh.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 2-20 mm.
Crystal shape: Semi-oikocrysts or anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-15%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Replacement of some olivine and clinopyroxene by amphibole, probably not much.
Plagioclase appears fresh.
Percent vein material: <1%.
Vein material: Pale green veins of amphibole ± epidote ± sodic plagioclase(?).



**118-735B-69R-4**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-4C**

**Olivine Gabbro**

**Pieces 1-4C**

**COLOR:** Gray speckled with grayish white

**LAYERING:** Size and modal layering apparent, layer contact gradational.

1) Coarse-grained clinopyroxene-rich (Pieces 1, 2, and 3). Olivine 8%, average 10 mm. Clinopyroxene 25%-30%, average 10 mm. Plagioclase 60%, average 15 mm.
2) Coarse-medium-grained (Pieces 1 and 2). Olivine 10%, average 7 mm. Clinopyroxene 25%, average 10 mm. Plagioclase 65%-70%, average 12 mm.
3) Coarse-grained clinopyroxene-poor (Piece 2). Olivine 15%, average 7 mm. Clinopyroxene 10%, average 5 mm. Plagioclase 75%, average 15 mm.
4) Medium-grained (Pieces 3 and 4A). Olivine 7%, average 4-3 mm. Clinopyroxene 30%, average 5 mm. Plagioclase 65%, average 10 mm.
5) Medium-grained subophitic. Olivine 5%, average 3 mm. Clinopyroxene 35%, average 7 mm Plagioclase 60%, average 8 mm, 5 mm where subophitic.

In Piece 4A, fairly subophitic portion present. Discontinuous layering in Pieces 4A and 4B inclining 45°.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

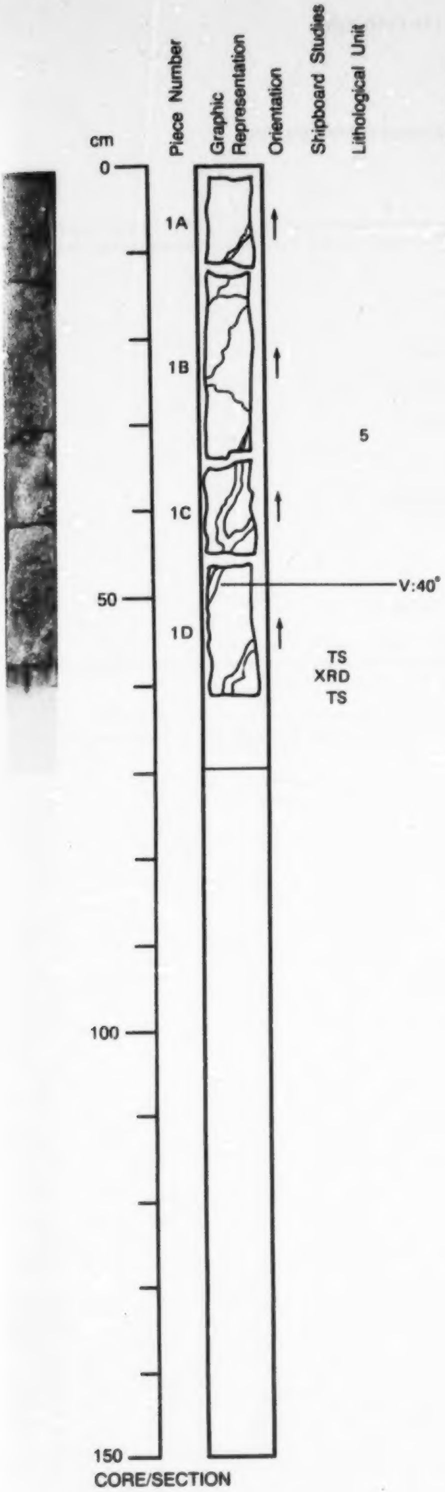
Plagioclase—Mode: See above.
Crystal size: See above.
Crystal shape: Anhedral-subhderal.
Preferred orientation: Not clear.
Percent replacement: None.

Clinopyroxene—Mode: See above.
Crystal size: See above.
Crystal shape: Anhedral
Preferred orientation: Not clear.
Percent replacement: <5% by amphibole.

Olivine—Mode: See above.
Crystal size: See above.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not clear.
Percent replacement: None.

**SECONDARY MINERALOGY:**

Total percent: <2%.
Texture: Amphibole replacing clinoyproxene, less than 5%. The rock is very fresh.
Percent vein material: Trace.
Vein material: Piece 2: Albite + prehnite(?) vein, 7 mm thick, dipping 65°.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
5
V:40°
TS
XRD
TS
CORE/SECTION

**118-735B-69R-5**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1D**

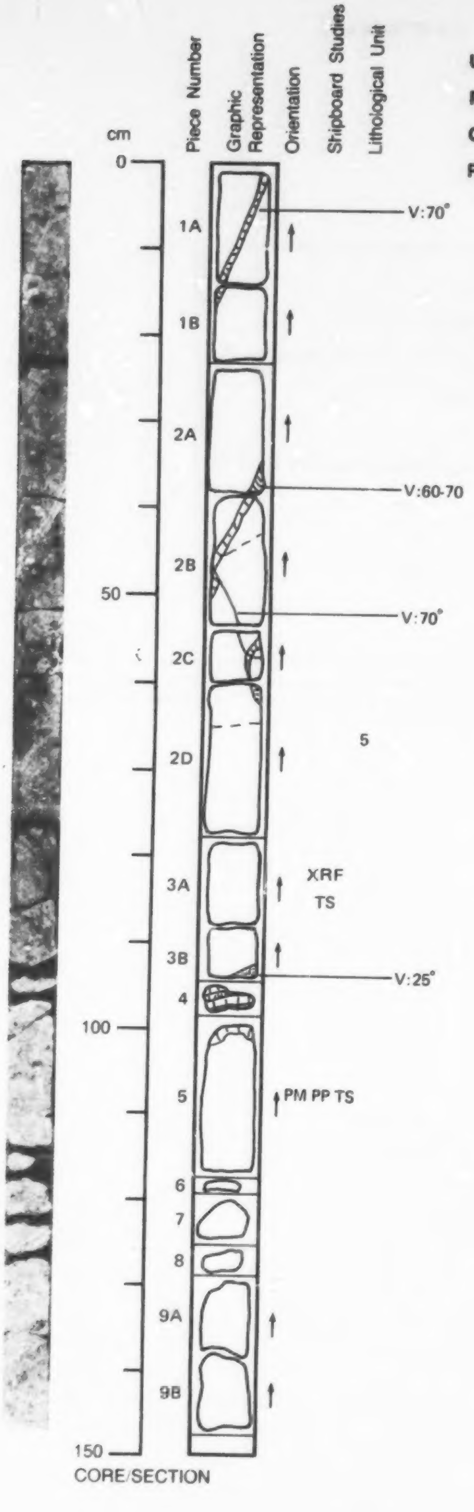
**Olivine Gabbro (cut by veins)**

**Pieces 1A-1D**

**COLOR:** Pinkish gray.
**LAYERING:** Massive.
**DEFORMATION:** None apparent except fractures with vein minerals.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 1-4 mm.
Crystal shape: Tabular to anhedral.
Preferred orientation: None.
Percent replacement: 15% by chlorite and sodic plagioclase.

Clinopyroxene—Mode: 37%-38%.
Crystal size: 2.5 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 15% by amphibole; more extensive near veins.

Olivine—Mode: 2%-3%.
Crystal size: 1 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: 50% by chlorite.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Not determined.
Percent vein material: 20%.
Vein material: Amphibole + epidote + sphene + albite; hornblende. Veins 1-1.25 cm wide contain coarse green epidote, large euhedral pink sphene + soft white bladed mineral (albite or analcite). Edges of veins are albitized plagioclase. There is substantial replacement of pyroxene by amphibole adjacent to veins.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2A
2B
2C
2D
3A
3B
4
5
6
7
8
9A
9B
V:70°
V:60-70
V:70°
V:25°
XRF
TS
PM PP TS
5
CORE/SECTION

**118-735B-70R-1**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-9B**

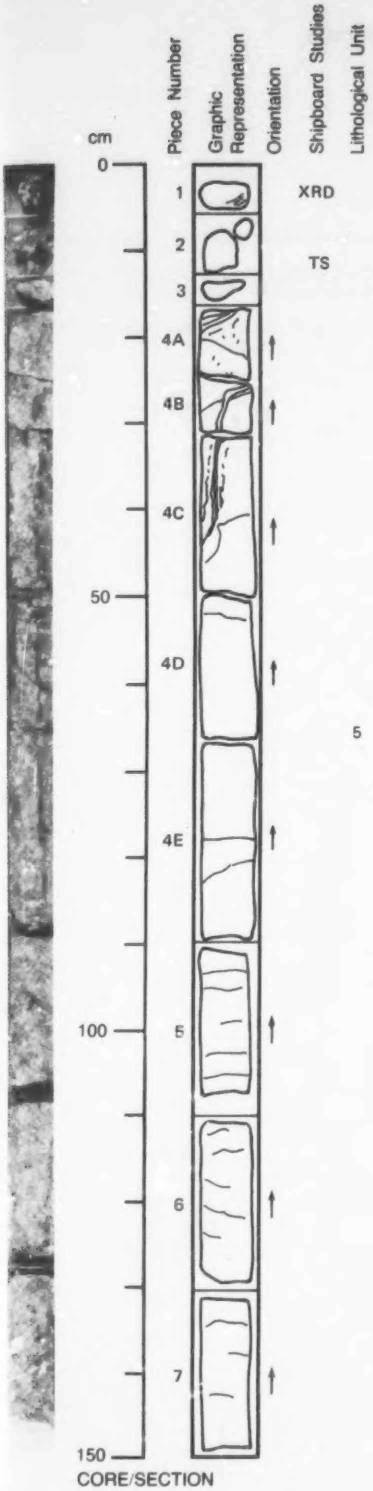
**Olivine Gabbro and Hydrothermally Altered Olivine Gabbro**

**Pieces 1A-9B**

**COLOR:** Gray to white.
**LAYERING:** Grain size variation: Pieces 1-2C are medium-grained, Pieces 2D and 3 are fine-grained. Some modal variations visible in Pieces 1, 2, and 3: olivine-rich intervals in Piece 2A and 2C. No magmatic lamination.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 0.3-1.5 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-35%.
Crystal size: 0.2 to 1.5 cm.
Crystal shape: Semi-oikocryst.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-20%.
Crystal size: 0.3-1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <15% in Pieces 1, 2, and 3, >30% in Pieces 4-9.
Texture: Amphibole partly replacing clinopyroxene and olivine, albitization of plagioclase especially along veins. the olivine is also partly oxidized.
Percent vein material: 1%-5%.
Vein material: Amphibole + epidote ± sodic plagioclase ± quartz. The veins are 1 mm to 4 cm thick. In Pieces 4-9, they form an anastomosed network and partly brecciate the gabbro.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4A
4B
4C
4D
4E
5
6
7
XRD
TS
5
CORE/SECTION

**118-735B-70R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-7**

**Olivine Gabbro**

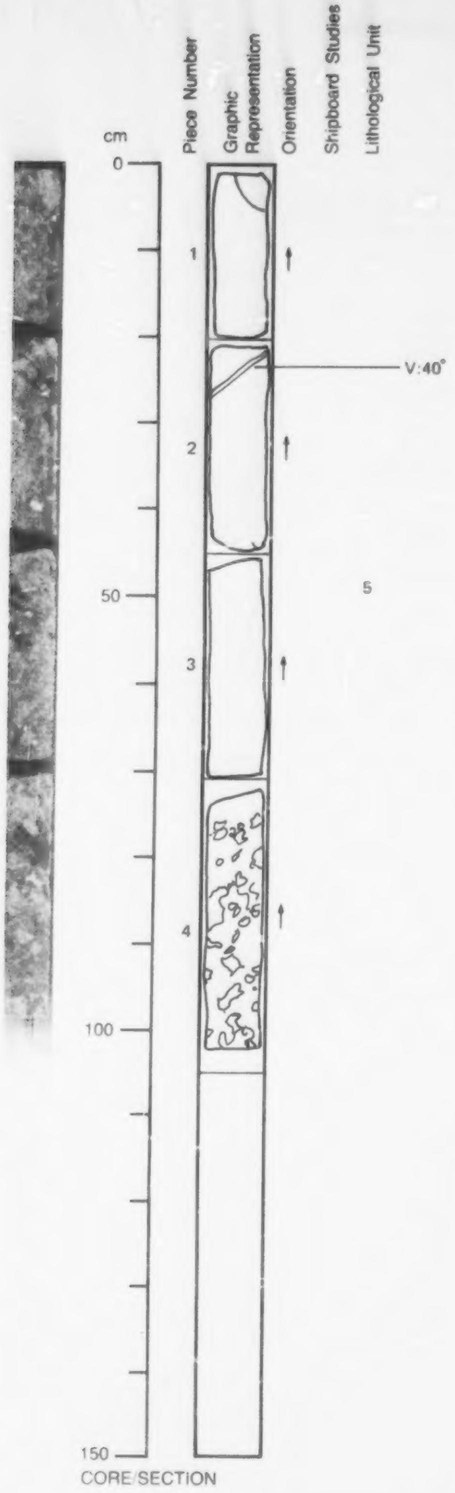
**Pieces 1-7**

**COLOR:** Gray; Yellowish-green along veins in Pieces 1 and 4A-C.
**LAYERING:** None; coarse-grained with only minor variations.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 0.5-3 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: <0.5-3 cm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: <5%-15%.
Crystal size: 0.3 to 2 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Olivine rimmed by alteration products (talc?), completely altered near major veins (Pieces 1, 4A, 4B, and upper 2/3 of Piece 4C) to yellowish-brown material. Clinopyroxene replacement by amphibole (<10%). Pieces 4A, 4B, and 4C are cut by thicker (up to 1 cm) vein, probably containing epidote, amphibole, feldspar(?), and some other secondary minerals. Only few veinlets with white minerals on other pieces of section.
**COMMENTS:** Pieces 2 and 3 constitute vein material: amphibole, epidote, plagioclase, carbonate(?), and opaques.



## 118-735B-70R-3

### UNIT 5: OLIVINE GABBRO

**Pieces 1-4**

**Olivine Gabbro**

**Pieces 1-4**

**COLOR:** Gray-dark gray.

**LAYERING:** Size layering is apparent. The contact between medium- and coarse-grained layers is vag and transitional.

1) Medium- to coarse-grained ophitic-subophitic (Pieces 1-3). Plagioclase 60%, 5-15 mm, euhedral-subhedral. Olivine 10%, 3-10 mm, subhedral. Clinopyroxene 20%, 5-15 mm, anhedral
2) Coarse-grained (Piece 4). Plagioclase 60%, 20-30 mm, subhedral-anhedral. Olivine 5%-7% 10 mm, subhedral. Clinopyroxene 33%, 5-25 mm, anhedral.

**DEFORMATION:** None apparent.

**PRIMARY MINERALOGY:**

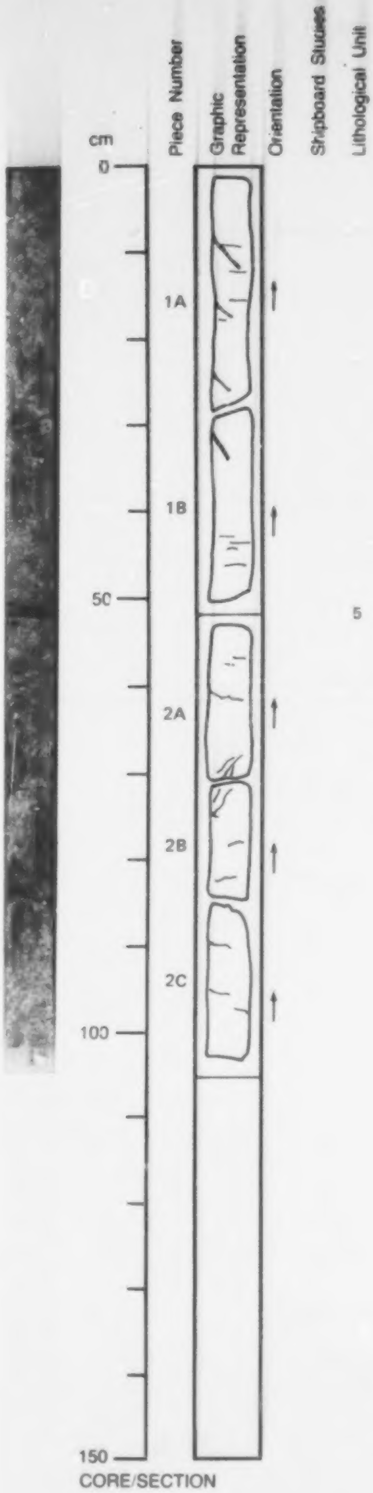
Plagioclase—Mode: See above.
Crystal size: See above.
Crystal shape: See above.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: See above.
Crystal size: See above.
Crystal shape: See above.
Preferred orientation: None.
Percent replacement: Trace by amphibole.

Olivine—Mode: See above.
Crystal size: See above.
Crystal shape: See above.
Preferred orientation: None.
Percent replacement: Trace by amphibole.

**SECONDARY MINERALOGY:**

Total percent: <1%.
Texture: Amphibole replacing clinopyroxene and olivine, <3%.
Percent vein material: Trace.
Vein material: Epidote vein, 4 mm thick, dipping 40°, present in Piece 2. Albite vein is present in Piece 1.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2A
2B
2C
5
CORE/SECTION

## 118-735B-70R-4

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-2C**

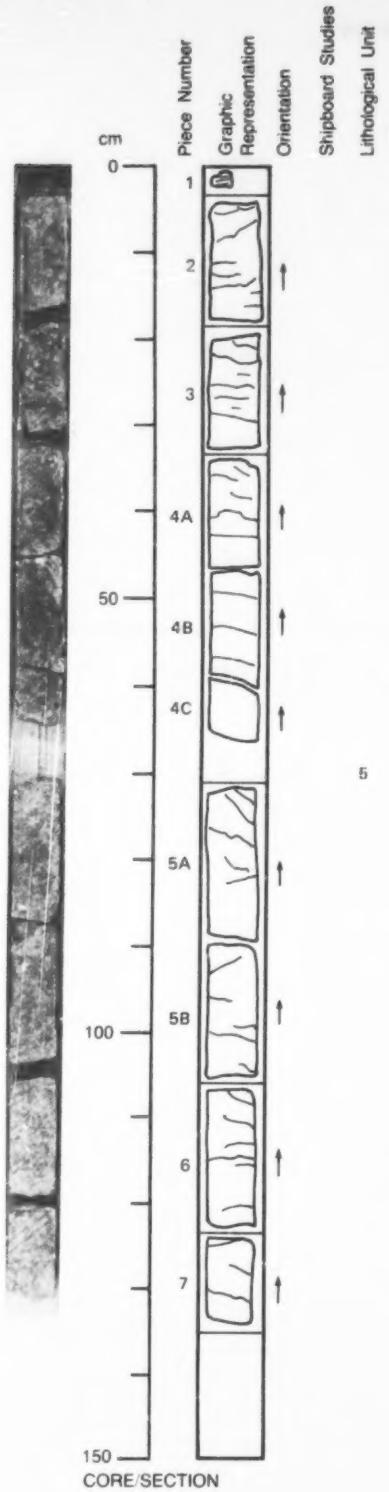
**Olivine Gabbro**

**Pieces 1A-2C**

**COLOR:** Gray.
**LAYERING:** No distinct layering.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 10-30 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacemente: Not determined.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 10-25 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%-20%.
Crystal size: 3-12 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Green amphibole replacing clinopyroxene. Tremolite + magnetite replacing olivine
Percent vein material: Not determined.
Vein material: Veins and halo in Pieces 2A and 2B contain green amphibole + epidote + sodic plagioclase(?) + minor sulfide (pyrite).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4A
4B
4C
5A
5B
6
7
5
CORE/SECTION

118-735B-71R-1

**UNIT 5: OLIVINE GABBRO**

**Pieces 1-7**

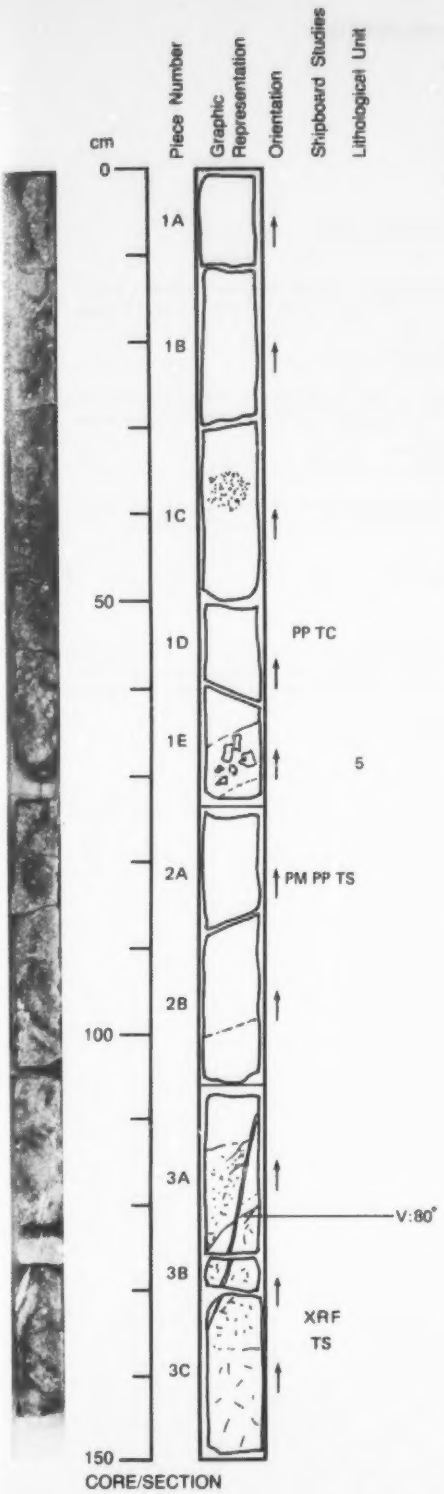
**Olivine Gabbro**

**Pieces 1-7**

**COLOR:** Medium gray.
**LAYERING:** None. Average grain size around 1 cm (<0.5 to locally 3 cm).
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 0.5-3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 0.4-3 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: <5% by amphibole.

Olivine—Mode: 5%-20% (probably >10% on average).
Crystal size: 0.3-2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Amphibole occasionally replacing clinopyroxene rims (<5%). Olivine mostly fresh. A few sulfides.
Percent vein material: Not determined.
Vein material: Few veinlets with white mineral(s).
**COMMENTS**: Piece 1: Tiny piece of rubble from somewhere higher up in the hole. Foliated metagabbro, (definately does not belong in this sequence).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
2A
2B
3A
3B
3C
PP TC
5
PM PP TS
V:80°
XRF
TS
CORE/SECTION

**118-735B-71R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3C**

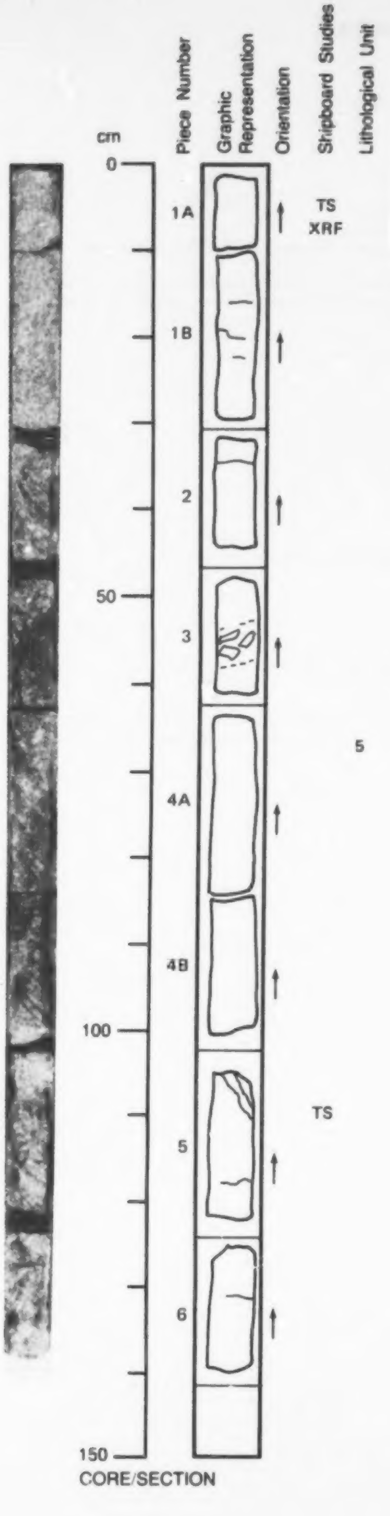
**Olivine Gabbro**

**Pieces 1A-3C**

**COLOR:** Gray, white where veined by epidote vein.
**LAYERING:** Apparent by variation in grain size and mode.
1) Medium-grained (Pieces 1A-1D and 2A-2C). Clinopyroxene: 5-10 mm, plagioclase: 5-10 mm, olivine: 2-6 mm.
2) Fine-grained (Piece 1C). Clinopyroxene: 1-3 mm, plagioclase: 2-5 mm, olivine: 1-2 mm.
3) Coarse-grained (Pieces 1E, 2B, and 3A). Clinopyroxene: 5-20 mm, plagioclase: 20-25, olivine: 5-10 mm. Layer contact is gradational.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-70%.
Crystal size: Variable, see above.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 15%-30%.
Crystal size: Variable, see above.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Trace by amphibole except near epidote(?) vein.

Olivine—Mode: 3%-10%.
Crystal size: Variable, see above.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Trace by amphibole except near epidote(?) vein.
**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Amphibole replacing clinopyroxene and olivine less than 5% except near epidote vein, which is 2-5 mm thick, jacketted by albite and prehnite(?). Near the vein amphibole abundance reaches 20%.
Percent vein material: Trace.
Vein material: Epidote(?).



**118-735B-71R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-6**

**Olivine Gabbro**

**Pieces 1A-6**

**COLOR:** Gray.
**LAYERING:** One coarse plagioclase-rich interval in Piece 3.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**

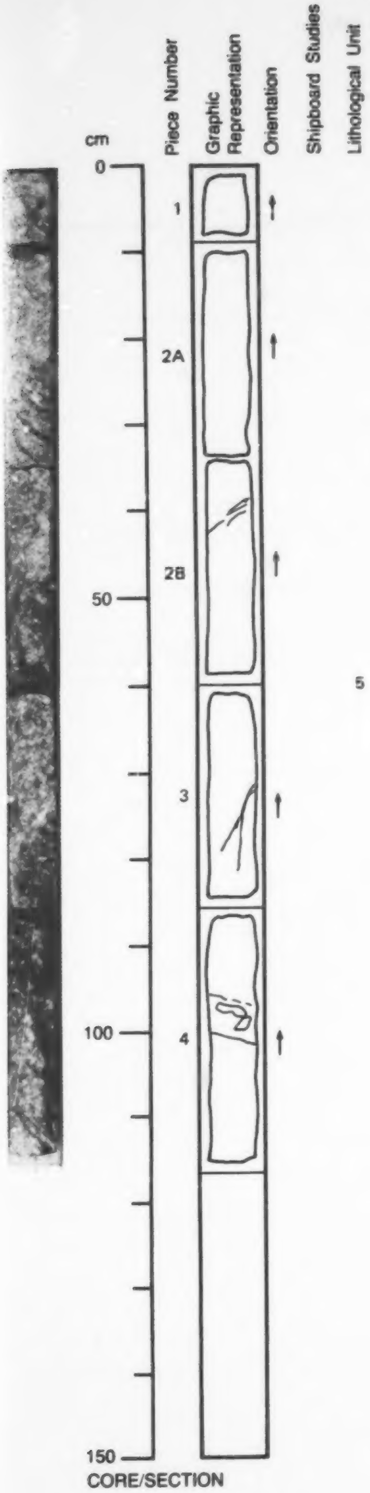
Plagioclase—Mode: 55% (medium-grained interval). 75% (coarse-grained interval).
Crystal size: 5-10 mm (medium-grained interval), 10-20 mm (coarse-grained interval).
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40% (medium-grained interval), 20% (coarse-grained interval).
Crystal size: 5-10 mm (medium-grained interval), 10-20 mm (coarse-grained interval).
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10% (medium-grained interval), 5% (coarse-grained interval).
Crystal size: 5 mm (medium-grained interval), 10 mm (coarse-grained interval).
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Clinopyroxene partly altered to amphibole. Pyrite commonly associated with amphibole. Quartz(?) vein in Piece 5 lined with green amphibole and epidote. Interior of vein has greasy appearance of quartz. Numerous white streaks that are subhorizontal may be granulated plagioclase.
Percent vein material: Not determined.
Vein material: Quartz(?), amphibole, and epidote.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2A
2B
3
4
5
CORE/SECTION

**118-735B-71R-4**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-4**

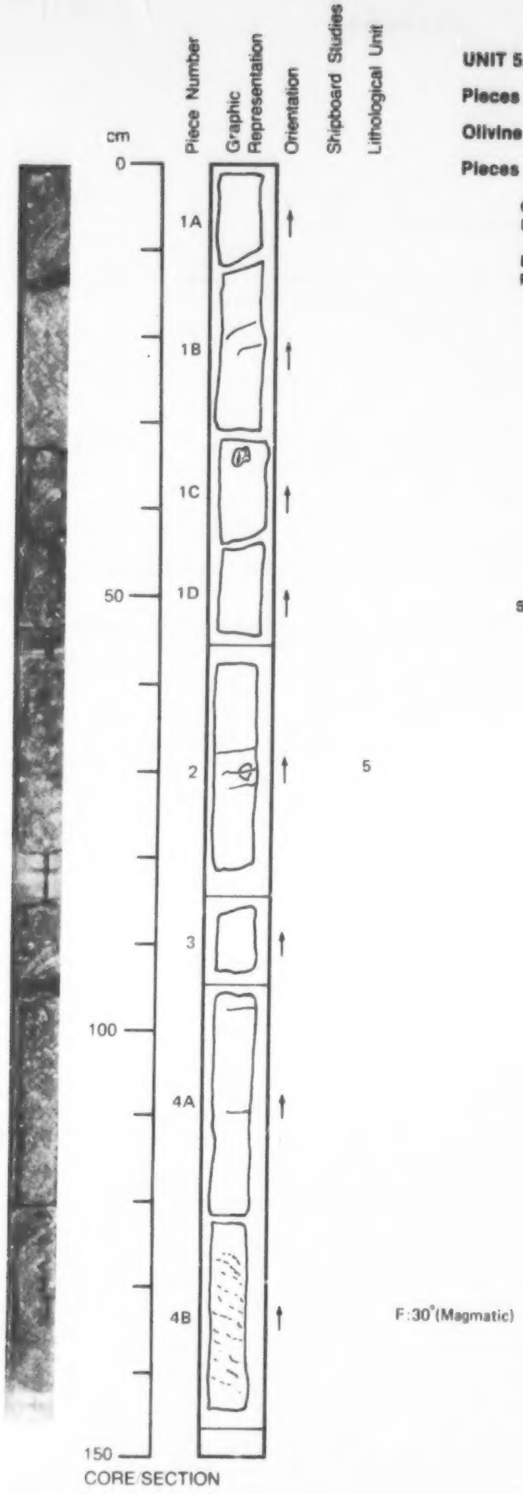
**Olivine Gabbro**

**Pieces 1-4**

**COLOR:** Gray.
**LAYERING:** One plagioclase-rich zone in Piece 4
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60% (up to 80% in plagioclase-rich interval).
Crystal size: 10-20 mm (up to 30 mm in plagioclase-rich interval).
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by amphibole.

Olivine—Mode: 10%-20%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by tremolite + magnetite with chloritic rim.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Olivine partly replaced by tremolite + magnetite with chloritic rim. Clinopyroxene partly replaced by amphibole. Minor pyrite associated with green amphibole. 1-3-mm-wide vein in Piece 3 contains epidote + actinolite + plagioclase.
Percent vein material: Not determined.
Vein material: Epidote, actinolite, and plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
2
3
4A
4B
5
F:30°(Magmatic)
CORE SECTION

## 118-735B-72R-1

## UNIT 5: OLIVINE GABBRO

### Pieces 1A-4B

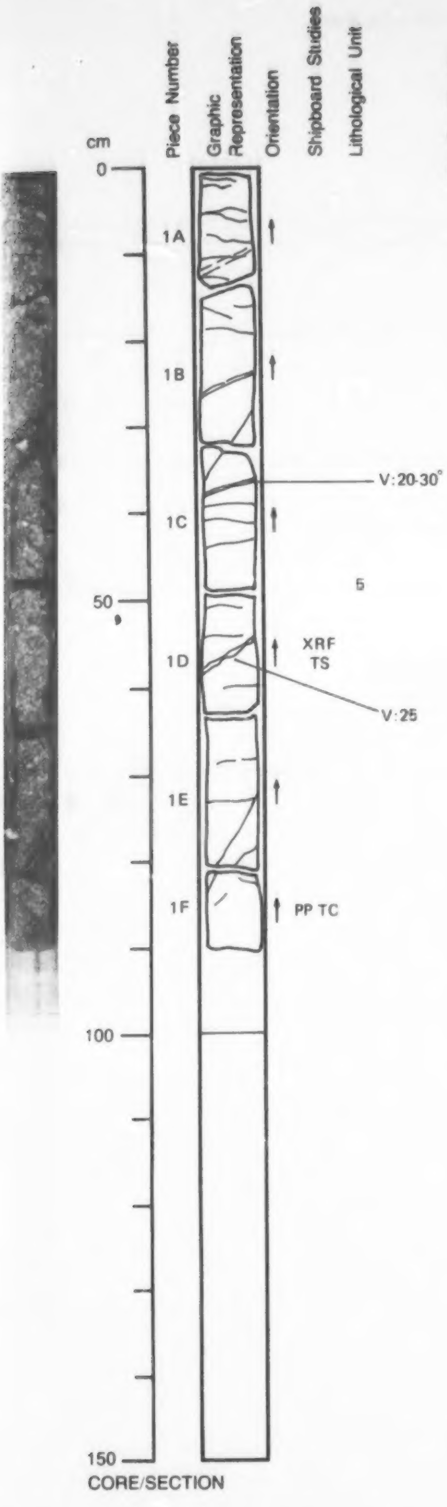
### Olivine Gabbro

### Pieces 1A-4B

**COLOR:** Gray.
**LAYERING:** Igneous lamination apparent in Piece 4B. Interval from Piece 1C to 4B exhibits reverse size grading.
**DEFORMATION:** None apparent
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-65%.
Crystal size: 1-5 mm in fine-grained intervals, 20 mm in coarse-grained intervals.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-35%.
Crystal size: 1-5 mm in fine-grained intervals, 20 mm in coarse-grained intervals.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Partly altered to amphibole.

Olivine—Mode: 5%-25%.
Crystal size: 0.5-2 mm in fine-grained intervals, 5 mm in coarse-grained intervals.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly altered to tremolite + magnetite. Chloritic rims.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Clinopyroxene partly altered to amphibole. Olivine partly altered to tremolite + magnetite. Sulfides occasionally occur on clinopyroxene rims, probably in association with amphibole replacement of clinopyroxene. Chloritic rims around olivine pseudomorphs and relicts.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
1F
V:20-30°
V:25
XRF
TS
PP TC
5
CORE/SECTION

**118-735B-72R-2**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-1F**

**Olivine Gabbro**

**Pieces 1A-1F**

**COLOR:** Gray.
**LAYERING:** Weak layering defined by size grading. Alternating medium- (average 0.3-0.8 cm) and coarse-grained (average 1.0-1.5 cm) bands. Inclination about 20°-30°.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

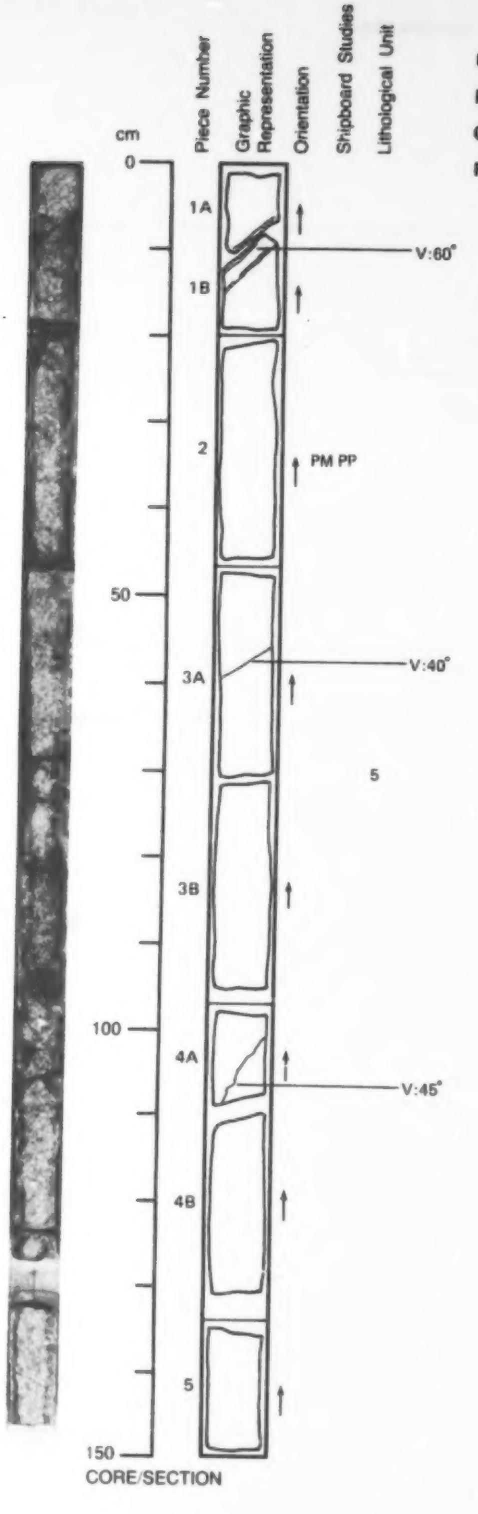
Plagioclase—Mode: 50%-60%.
Crystal size: 0.4-2.5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: <0.4-3 cm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 0.3-2 cm
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly altered.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine partly altered (especially along the rims), some amphibole replacement of clinopyroxene (<10%). Oxidation (brown olivine pseudomorphs), along veins in Piece 1E. Few sulfides.
Percent vein material: Not determined.
Vein material: Minor veins and veinlets, filled with amphibole, feldspar(?) + some light bluish mineral (Piece 1A).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3A
3B
4A
4B
5
V:60°
V:40°
V:45°
PM PP
5
CORE/SECTION

**118-735B-72R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-5**

**Olivine Gabbro**

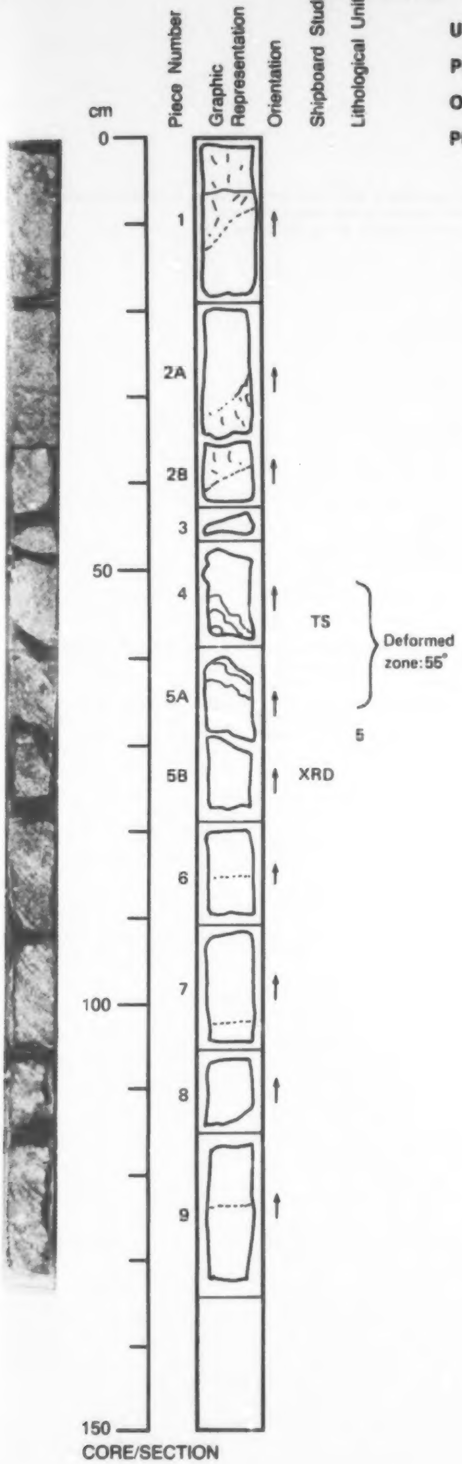
**Pieces 1A-5**

**COLOR:** Gray.
**LAYERING:** Grain size changes from medium, to coarse, from Piece 1A to Piece 3B and decreases to Piece 5. Grading is almost a meter-scale. Olivine is rich in Pieces 4B and 5. Inclination of layering not clear.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 2-5 mm (in medium-grained interval, Pieces 1A and 1B), 4-12 mm (in coarse-grained interval, Piece 3B).
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 20%-30%.
Crystal size: 2-5 mm (in medium-grained interval, Pieces 1A and 1B), 3-7 mm (in coarse-grained interval, Piece 3B).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 2-4 mm (in medium-grained interval, Pieces 1A and 1B), 3-8 mm (in coarse-grained interval, Piece 3B).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Amphibole after clinopyroxene and olivine. Near calcite veins oxidation of olivine and clinopyroxene is apparent.
Percent vein material: Trace.
Vein material: The calcite veins are 1 mm thick, and are inclined at 60° (Pieces 1A, 3A, and 4A).
**COMMENTS:** Locally subophitic.

## 118-735B-72R-4


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2A
2B
3
4
5A
5B
6
7
8
9
TS
XRD
Deformed zone: 55°
5
CORE/SECTION

### UNIT 5: OLIVINE GABBRO

**Pieces 1-9**

**Olivine Gabbro**

**Pieces 1-9**

**COLOR:** Dark gray.

**LAYERING:** Grainsize variations: Piece 1 (top) is coarse (≤1.5 cm); Piece 1 (bottom) to Piece 2A (top) is fine-grained (<0.5 cm); Piece 2A (bottom) to Piece 2B (top) is coarse-grained (<2.5 cm); Piece 2B (bottom) to Piece 7 (bottom) is fine-grained (0.3-0.9 cm); Piece 7 (bottom) to Piece 9 (top) is coarse-grained (≤3 cm) and Piece 9 (bottom) is < 0.9 cm. No modal variation.

**DEFORMATION:** Deformed zone wih porphyroclastic texture and brittle crushing, Pieces 4 and 5A.

**PRIMARY MINERALOGY:**

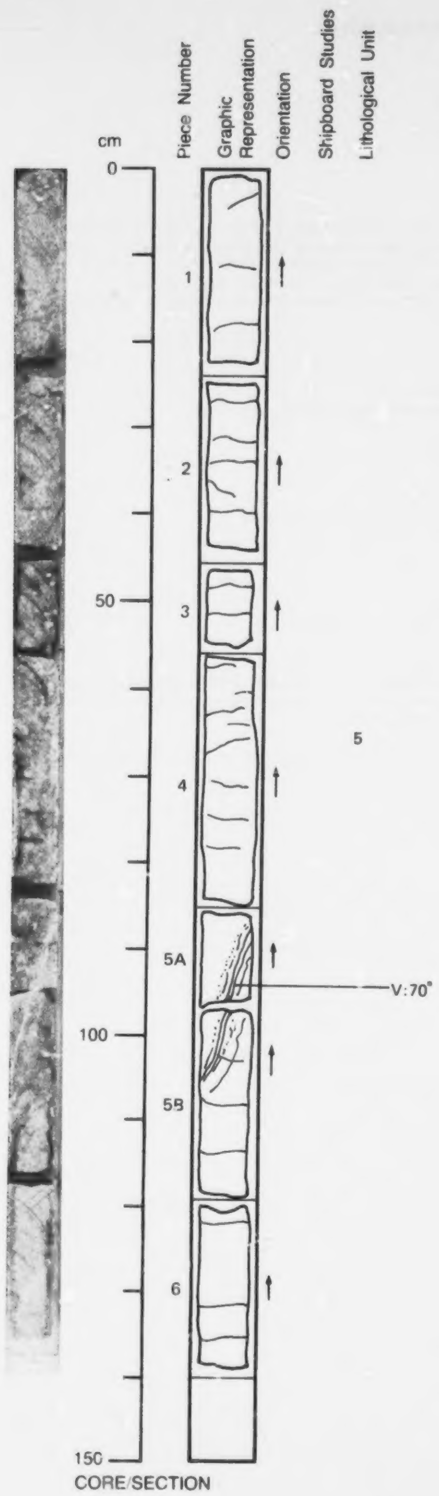
Plagioclase—Mode: 50%-60%.
Crystal size: See above.
Crystal shape: Subhedral.
Preferred orientation: None apparent.
Percent replacement: In deformed zones only, by sodic plagioclase.

Clinopyroxene—Mode: 35%-45%.
Crystal size: See above.
Crystal shape: Subhedral.
Preferred orientation: None apparent.
Percent replacement: 100% in deformed zone by amphibole.

Olivine—Mode: <10%.
Crystal size: See above.
Crystal shape: Anhedral.
Preferred orientation: None apparent.
Percent replacement: 2%-5% by chlorite or hematite.

**SECONDARY MINERALOGY:**

Total percent: 10%.
Texture: Large deformed zone with hydrothermal alteration. Crushed clinopyroxene mixed with epidote. large red hematite pseudomorphs. Much iron-staining and albitized plagioclase.
Porphyroclastic. Intense oxidative alteration.
Percent vein material: 2%.
Vein material: Hornblende + sodic plagioclase. Pieces 1, 2A, and 2B: Small white veins, some with amphibole, dip 10°-15°.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5A
5B
6
5
V:70°
CORE/SECTION

**118-735B-72R-5**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-6**

**Olivine Gabbro**

**Pieces 1-6**

**COLOR:** Gray.
**LAYERING:** Weak layering, defined by gradation in grain size, medium- to coarse-grained bands (0.5-1.0 cm) are alternating with coarse-grained bands (1.5-2 cm).
**DEFORMATION:** In general, none; slight deformation along vein in Piece 5.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 0.4-3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 0.3-3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: <0.4-2.5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Partially altered.

Sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Some amphibole replacement of clinopyroxene (<10%); olivine partially altered.
Stronger alteration along veins, especially on Pieces 5A and 5B.
Percent vein material: Not determined.
Vein material: One major vein through Pieces 5A and 5B, filled with white and green minerals, dips 70°.

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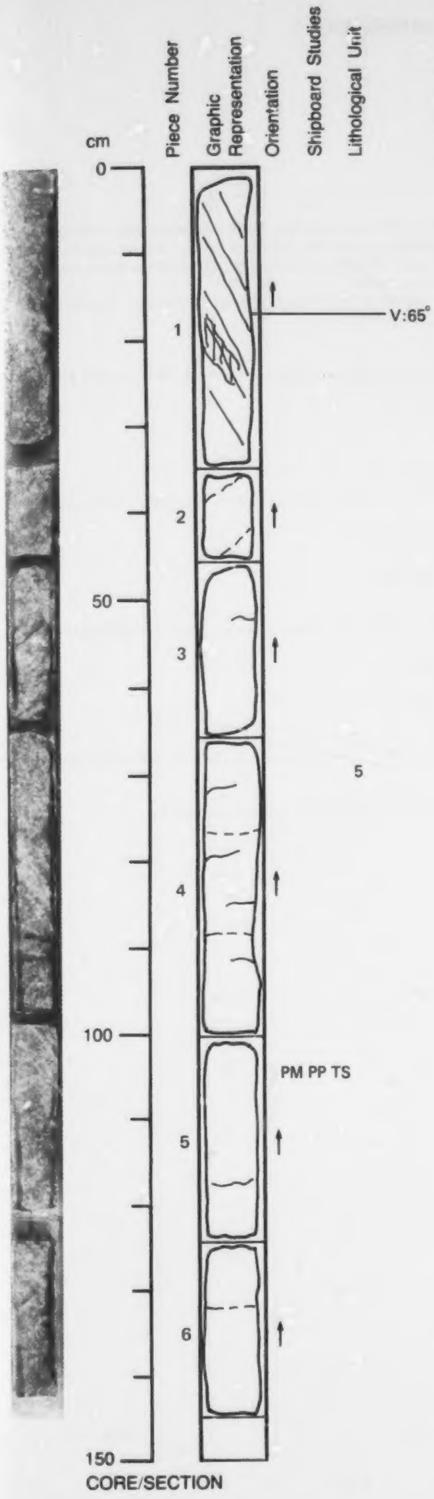
## 118-735B-72R-6


cm
0
50
100
150
CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
1
2
3
4
5
6
V:65°
5
PM PP TS

### UNIT 5: OLIVINE GABBRO

**Pieces 1-6**

**Olivine Gabbro**

**Pieces 1-6**

**COLOR:** Gray.

**LAYERING:** Grain size variations: ≤1 cm from 0 to 35 cm; ≤1.5 cm from 35 to 65 cm; ≤0.5 cm from 65 to 75 cm; ≤1 cm from 75 to 90 cm; and ≤0.5 cm below 90 cm. Modal variation: olivine-rich intervals in Pieces 1, 2, 4, and 6. No magmatic layering.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

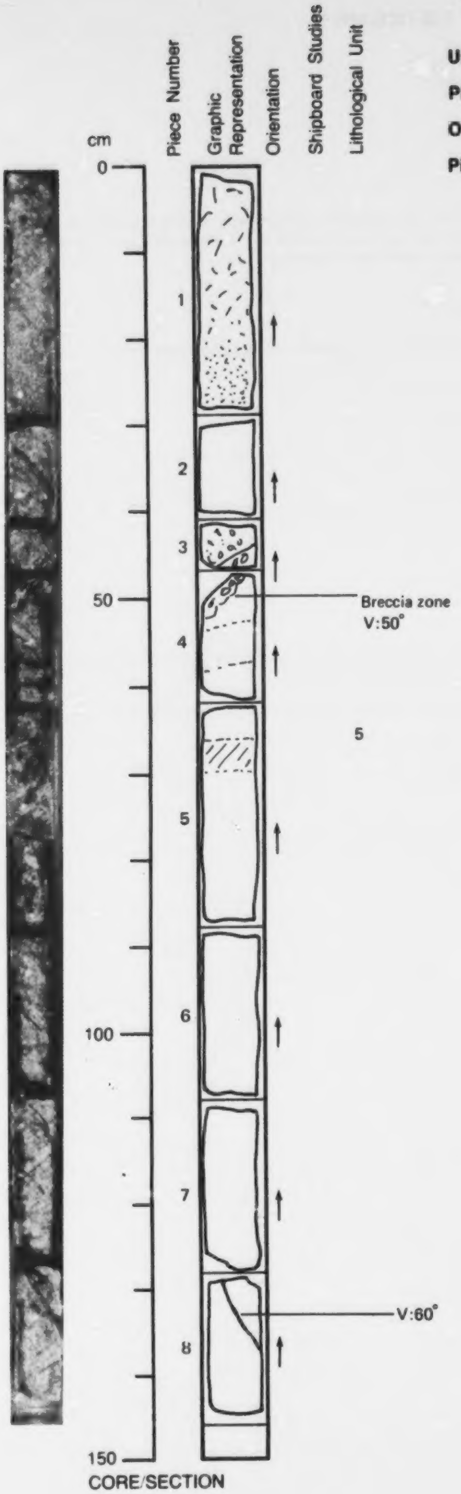
Plagioclase—Mode: 50%-60%.
Crystal size: See layering.
Crystal shape: Euhedral to subhedral, often partially included in clinopyroxene.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-35%.
Crystal size: See layering.
Crystal shape: Oikocrysts.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-20%.
Crystal size: See layering.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight.
Texture: Slight replacement of clinopyroxene and olivine by amphibole and albitization of plagioclase—particularly visible along veins in Piece 1.
Percent vein material: <1%.
Vein material: Thin amphibole veins and also very thin subhorizontal white veins.



**118-735B-72R-7**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-8**

**Olivine Gabbro**

**Pieces 1-8**

**COLOR:** Gray.

**LAYERING:** Defined by grain size variation and modal variation. Piece 1 shows reverse grading: the top is 6-15 mm and the bottom is 2-3 mm in grain size. Olivine is richer in the bottom (20%) than in the top (7%). Piece 3 shows apparent foliation defined by clinopyroxene shape orientation. In Pieces 4 and 5 olivine-rich zones appear.

**DEFORMATION:** In Piece 3 and 4, brecciated zone 2 cm thick is present. Plagioclase is albitized and clinopyroxene is amphibolitized in the zone.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: 10 mm (in medium-grained interval, Pieces 4 and 5), 15 mm (in coarse-grained interval, Piece 6).
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: None.

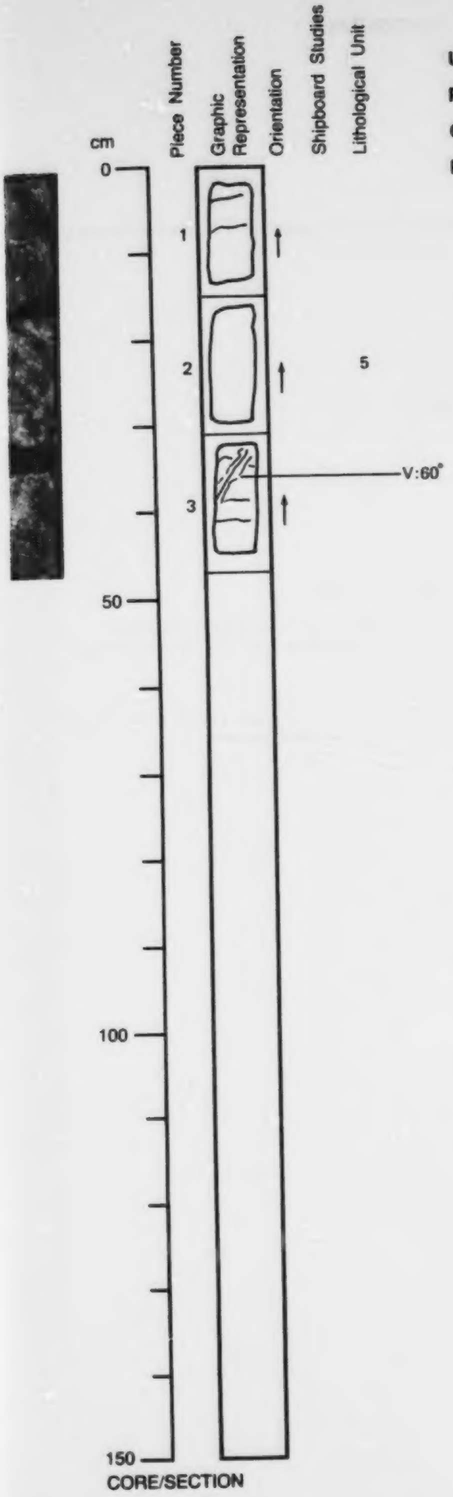
Clinopyroxene—Mode: 15%-30%.
Crystal size: 7 mm (in medium-grained interval, Pieces 4 and 5), 10 mm (in coarse-grained interval, Piece 6).
Crystal shape: Anhedral, rarely subhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Olivine—Mode: 7%-20%.
Crystal size: 7 mm (in medium-grained interval, Pieces 4 and 5), 7 mm (in coarse-grained interval, Piece 6).
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Almost none.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Amphibole after clinopyroxene. In brecciated zone in Piece 4, amphibolitization is strong.
Percent Vein material: Trace.
Vein material: Albite vein 0.5 mm thick, inclining 60° appears in Piece 8.

**118-735B-72R-8**


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
5
V:60°
CORE/SECTION

## UNIT 5: OLIVINE GABBRO

**Pieces 1-3**

**Olivine Gabbro**

**Pieces 1-3**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 8-25 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%-40%.
Crystal size: 8-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by tremolite + magnetite. Chloritic rims.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Olivine partly replaced by tremolite + magnetite. Chloritic rims around olivine pseudomorphs and relicts. Clinopyroxene partly replaced by green amphibole.
Percent vein material: Not determined.
Vein material: Thin (0.5 mm) veins in Piece 3 with green amphibole.

**118-735B-73R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-4**

**Olivine Gabbro**

**Pieces 1-4**

**COLOR:** Gray.

**LAYERING:** No grain size layering; intervals with higher modal percent of olivine in Pieces 2 and 3B. No magmatic lamination.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Partly albitized.

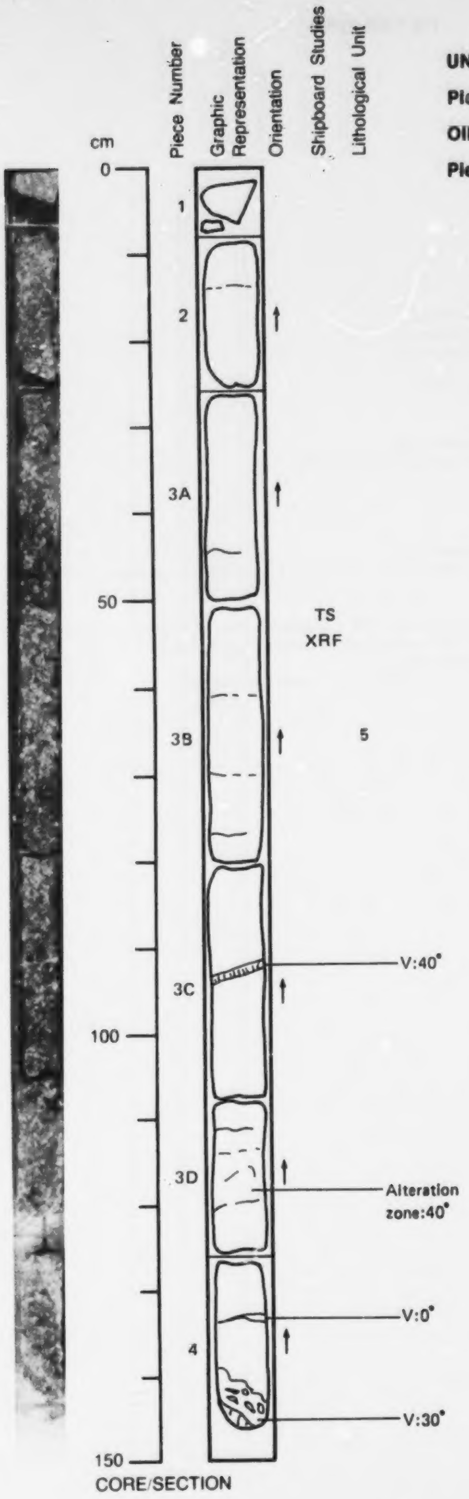
Clinopyroxene—Mode: 25%-35%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Partly replaced by amphibole.

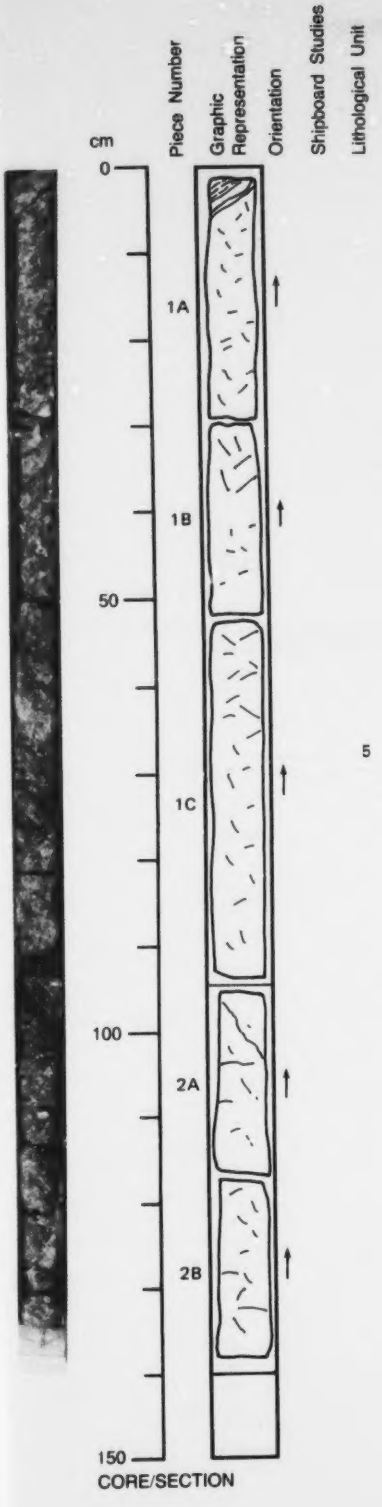
Olivine—Mode: 5%-15%.
Crystal size: 2-15 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Partly replaced by amphibole.

**SECONDARY MINERALOGY:**

Total percent: Slight (in Pieces 1, 2, and 3A-C) to extensive (in Pieces 3D and 4).
Texture: Amphibole replaces clinopyroxene and olivine. Plagioclase is partly albitized, especially in Pieces 3D and 4.
Percent vein material: 1%-2%.
Vein material: Amphibole ± epidote ± sodic plagioclase.

**COMMENTS:** The amphibole ± epidote veinlet in Piece 4 is rich in iron-titanium oxides. The altered zones of Pieces 3D and 4 contain up to 10% iron-titanium oxides.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3A
3B
3C
3D
4
TS
XRF
5
V:40°
Alteration zone:40°
V:0°
V:30°
CORE/SECTION



118-735B-73R-2

## UNIT 5: OLIVINE GABBRO

### Pieces 1A-2B

### Olivine Gabbro

### Pieces 1A-2B

**COLOR:** Gray.

**LAYERING:** Some grain size variation. Most of core is medium grained with two intervals of coarser to fine gradations (35-10 cm, and 63-45 cm).

**DEFORMATION:** A few fractures, and epidotized shear zone at top of Piece 1A.

**PRIMARY MINERALOGY:**

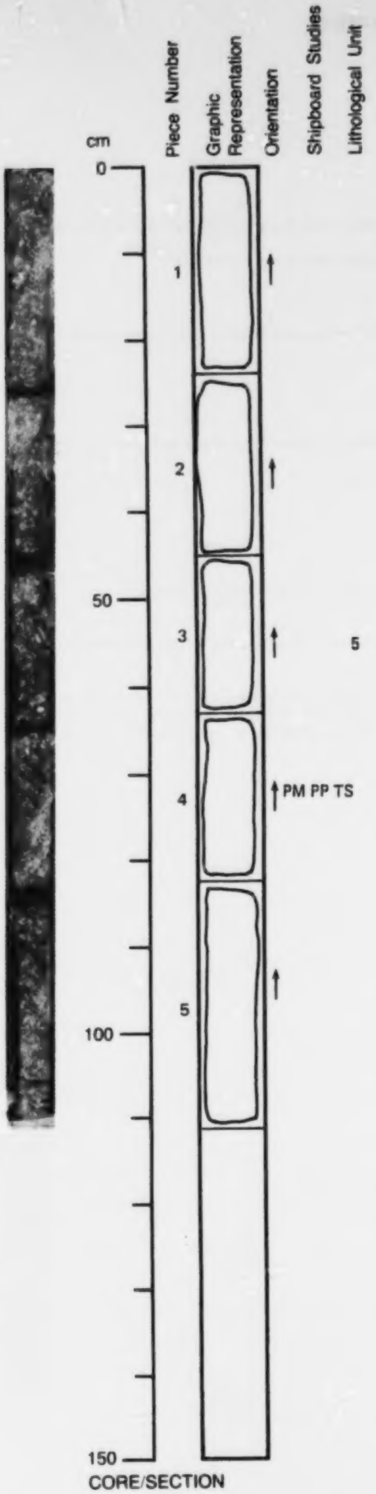
Plagioclase—Mode: 40%-60%.
Crystal size: 1-22 mm.
Crystal shape: Euhedral where small and enclosed, subhedral to anhedral elsewhere.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-60%.
Crystal size: 3-30 mm.
Crystal shape: Anhedral, interstitial to poikilitic, subhedral in coarser section.
Preferred orientation: Not determined.
Percent replacement: Partially amphibolitized.

Olivine—Mode: 2%-5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral to subrounded.
Preferred orientation: Not determined.
Percent replacement: Altered to dark vein network of amphibole and talc

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine partly altered to amphibole, talc, and opaques, clinopyroxene partially amphibolitized near veins. Trace of pyrite.
Percent vein material: Not determined.
Vein material: There are some very fine fractures and veins throughout sample. One large vein cutting top of Piece 1A looks like replacement of a shear zone. It includes a strong foliation and has epidote, albite, and carbonate, and hematite(?) stain. There is a red-pink color to the vein.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CORE/SECTION

**118-735B-73R-3**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-5**

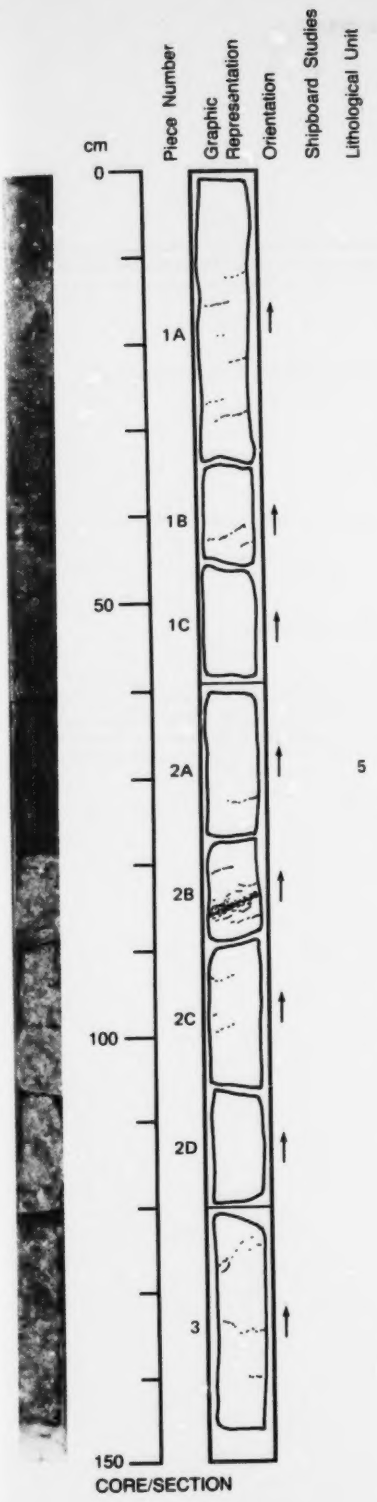
**Olivine Gabbro**

**Pieces 1-5**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Clinopyroxene—Mode: 45%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Olivine—Mode: 5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20% by clay or serpentine.
**SECONDARY MINERALOGY:**
Total percent: 1%-2%.
Texture: Olivine altered in mesh-like fashion to black mineral, maybe clay or serpentine. Very minor replacement of clinopyroxene and plagioclase by amphibole.
Percent vein material: 0%.
Vein material: None.


cm
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Lithological Unit
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CORE/SECTION

## 118-735B-73R-4

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-3**

**Olivine Gabbro**

**Pieces 1A-3**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

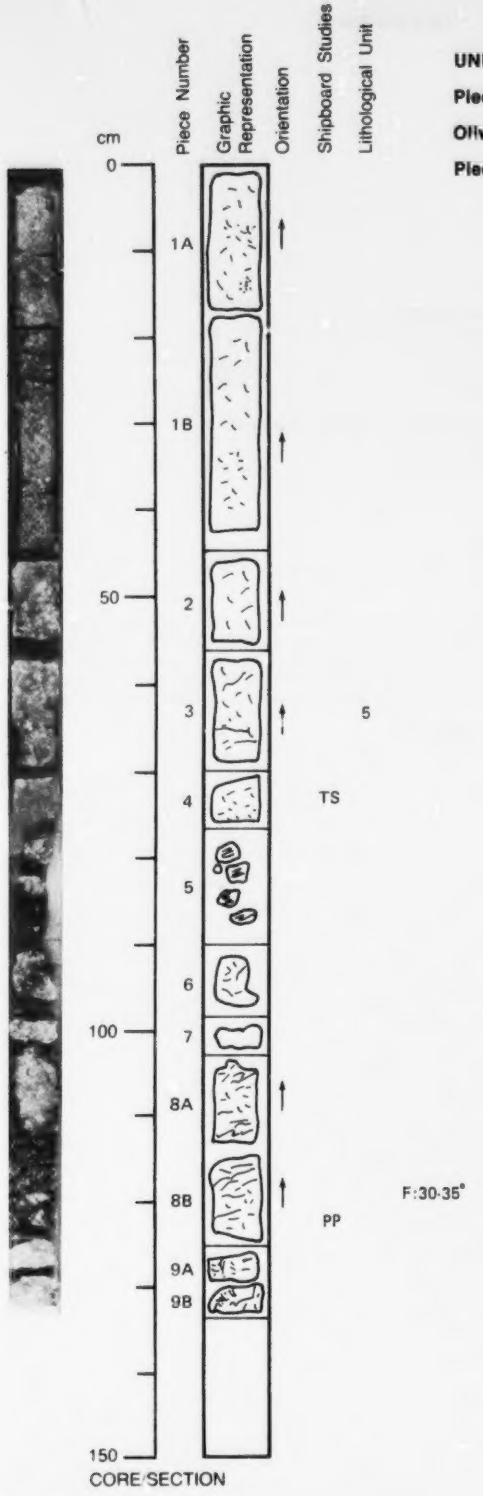
Plagioclase—Mode: 50%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 45%.
Crystal size: 3-15 mm.
Crystal shape: Subhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%.
Crystal size: 3-10 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 10-20% oxidized to an orange-brown color.

**SECONDARY MINERALOGY:**

Total percent: <1%.
Texture: Most of the section is extremely fresh. Numerous very thin, nearly horizontal white veins, maybe plagioclase; almost no amphibole. Piece 2B has a 1 cm wide zone of opaques, probably ilmenite. For about 4 cm to either side of this vein, olivine is oxidized to an orange-brown color, but only along crack surfaces; much of core is still fresh. Slightly more total amphibole, also adjacent to this vein, but still only about 1-2% of total. Trace of sulfides throughout.
Percent vein material: Not determined.
Vein Material: Sodic plagioclase.



**118-735B-73R-5**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-9B**

**Olivine Gabbro**

**Pieces 1A-9B**

**COLOR:** Gray.

**LAYERING:** Some coarse to fine variation.

**DEFORMATION:** Slight in top 75 cm. Mylonitic and poorly foliated gabbro in Piece 5. Bottom of core is a sheared and brecciated metagabbro with a variously developed foliation dipping 30°. Bands and pods of whitish, granulated feldspar common on brecciated sections. May be some feldspathic vein material as well.

**PRIMARY MINERALOGY:**

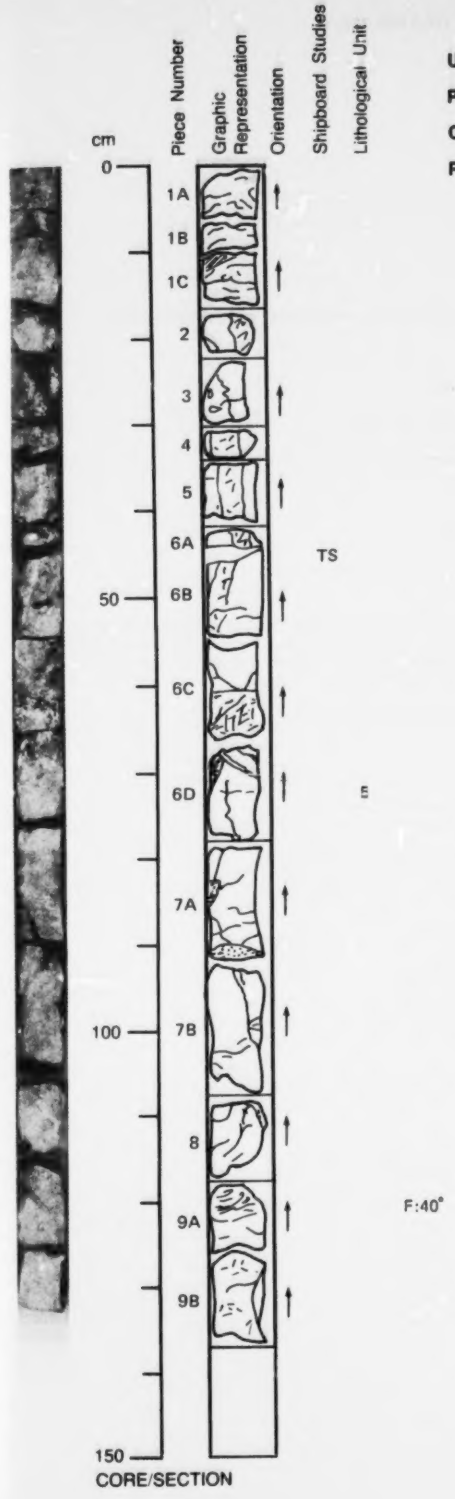
Plagioclase—Mode: 40%-60%.
Crystal size: 3-10 mm.
Crystal shape: Euhedral when in clinopyroxene, subhedral to anhedral elsewhere.
Preferred orientation: None.
Percent replacement: Minor albitization.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Up to 50% replacement by amphibole in deformed zones.

Olivine—Mode: 2%-5%.
Crystal size: 2-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Commonly to magnetite-tremolite-talc.

**SECONDARY MINERALOGY:**

Total percent: Up to 50%-60%.
Texture: Amphibolitization of clinopyroxene extensive in deformed part of core. A concentration of opaques (up to 10% modally) at top of deformed zone. The occurrence suggests a secondary origin for the opaques. Olivine commonly altered to talc-tremolite-magnetite. There is likely some albitization of plagioclase in deformed zone. There is minor pyrite in the undeformed gabbro and a secondary sulfide occurs on fracture surfaces in Piece 5.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-73R-6

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-9B**

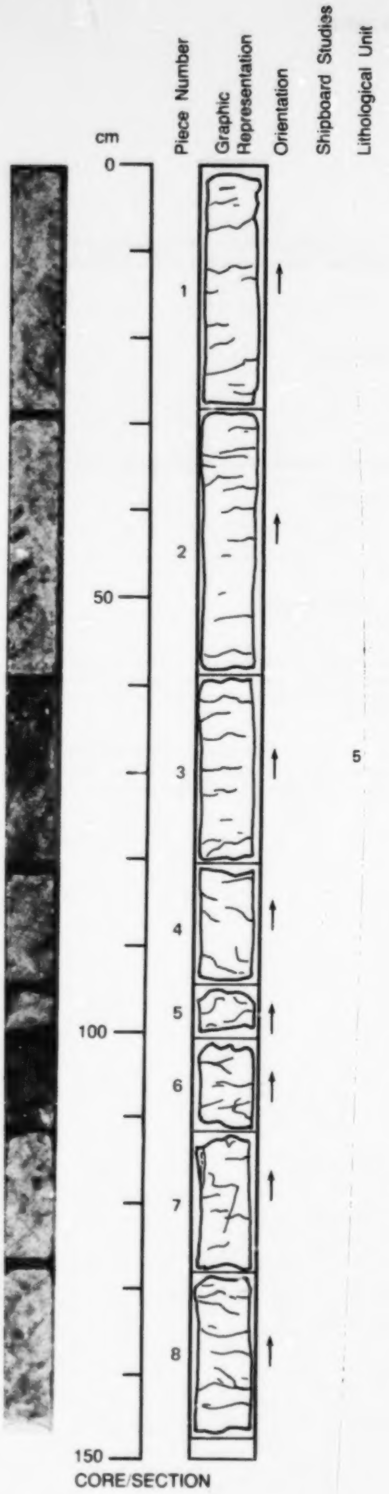
**Olivine Gabbro**

**Pieces 1A-9B**

**COLOR:** Gray to greenish gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Visible in Pieces 1A, 1B, 1C, 6C, and 9A. Small shear 2 cm thick or foliation defined by preferred orientation of pyroxene and plagioclase. Grain size 2-3 mm in deformed zones, 4-7 mm in undeformed gabbro.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size. 1-6 mm.
Crystal shape: Euhedral, included in clinopyroxene.
Preferred orientation: Locally present.
Percent replacement: None.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-20 mm.
Crystal shape: Oikocrystic type with numerous inclusions (chadacrysts) of plagioclase.
Preferred orientation: Locally present.
Percent replacement: Severely altered to amphibole.

Olivine—Mode: 2%-5%.
Crystal size: 1-5 mm.
Crystal shape: Irregular, interstitial.
Preferred orientation: Locally present.
Percent replacement: 50% by serpentine or chlorite and talc.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic, coronitic. Olivine is partly (50%) replaced by dark serpentine or chlorite and bluish-gray talc. Clinopyroxene is largely replaced by green amphibole in veined areas (Pieces 2 to 6D), and where the rock is affected by deformation (Pieces 1A-C, 6C, and 9A). Sulfides are observed in Pieces 3 and 9B.
Percent vein material: Not determined.
Vein material: Plagioclase and amphibole. Vein (1.5 cm thick) filled by plagioclase and amphibole. Coronitic reaction around pyroxene indicate these veins are preferred injection of plagioclase into former gabbro. Late cracks and veinlets filled with amphibole and plagioclase.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Orientation
Shipboard Studies
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CORE/SECTION

**118-735B-73R-7**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1-8**

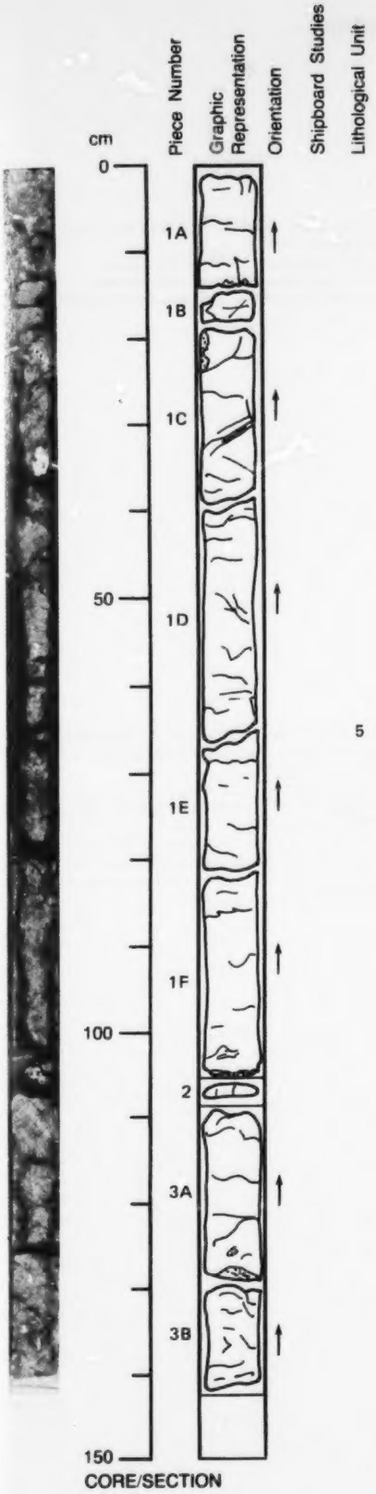
**Olivine Gabbro**

**Pieces 1-8**

**COLOR:** Gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-6 mm.
Crystal shape: Euhedral when enclosed in clinopyroxene, to subhedral in matrix.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 4-30 mm.
Crystal shape: Subhedral of oikocrystic type.
Preferred orientation: Not determined.
Percent replacement: 40% by amphibole.

Olivine—Mode: 10%-15%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral to rounded.
Preferred orientation: Not determined.
Percent replacement: 30% by serpentine or chlorite + magnetite.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Pseudomorphic, coronitic. Olivine is replaced (30%) by dark serpentine or chlorite + magnetite. Plagioclase is invaded by amphibole veinlets. Clinopyroxene partially (40%) replaced by amphibole along cleavage or cracks. Sulfides disseminated through the rock. Larger sulfide spots (up to 1.5 mm) in Pieces 1, 2, 5, 7, and 8.
Percent vein material: 20%.
Vein material: Late white cracks filled by amphibole (<1 mm).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CORE/SECTION

**118-735B-74R-1**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-3B**

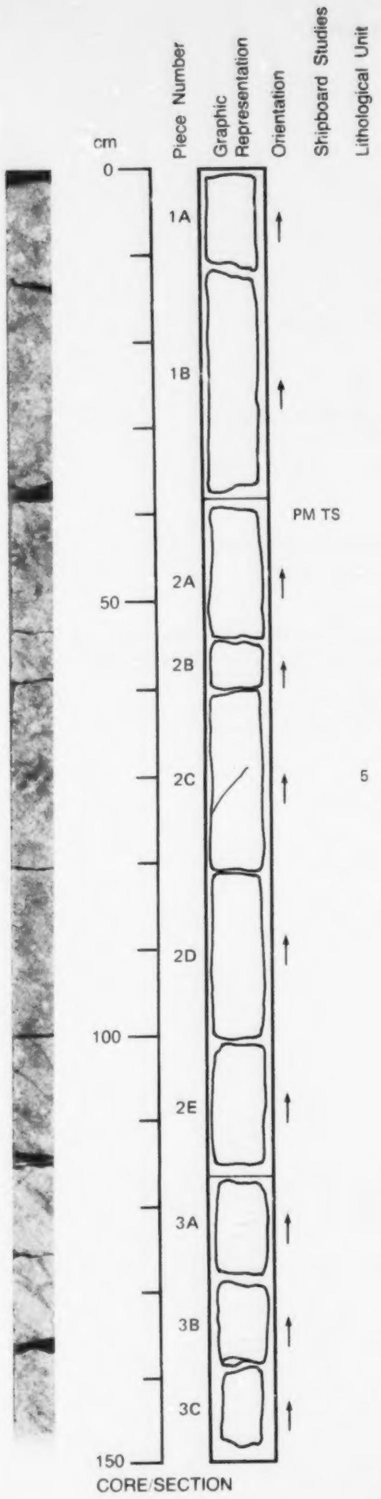
**Olivine Gabbro**

**Pieces 1A-3B**

**COLOR:** Gray.
**LAYERING:** Not present. Coarse-grained gabbro.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-30 mm.
Crystal shape: Euhedral and enclosed in clinopyroxene.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 5-50 mm enclosing other major silicate phases.
Crystal shape: Oikocrystic, euhedral to anhedral.
Preferred orientation: None.
Percent replacement: 20% by amphibole.

Olivine—Mode: 10%.
Crystal size: 1-8 mm.
Crystal shape: Rounded, interstitial or included in clinopyroxene.
Preferred orientation: None.
Percent replacement: 30% by serpentine or chlorite and talc.
**SECONDARY MINERALOGY:**
Total percent: 15%.
Texture: Coronitic, pseudomorphic. Olivine is altered (near 30%) to dark yellow green serpentine or chlorite and talc. Clinopyroxene is slightly (20%) replaced by amphibole.
Sulfides (pyrite) up to 1.5 mm across are present in Pieces 1A, 1E, 1F, 3A, and 3B.
Percent vein material: 1%.
Vein material: Amphibole. Cracks and veinlets are filled with blue green amphibole (small shear zones). Cracks in plagioclase are filled with green amphiboles.



## 118-735B-74R-2

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3C**

**Olivine Gabbro**

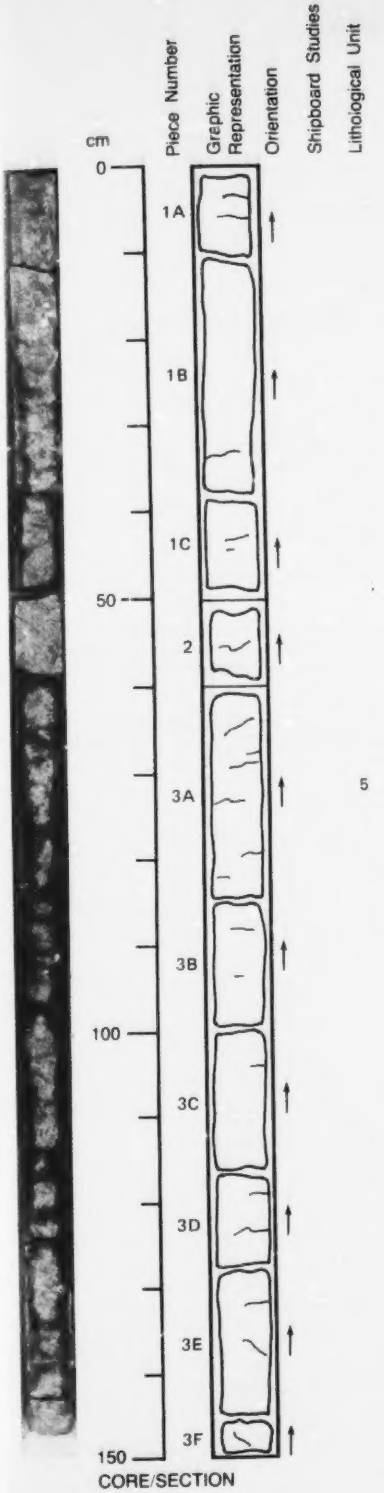
**Pieces 1A-3C**

**COLOR:** Gray.
**LAYERING:** Isotropic with no obvious igneous layering due to size grading or lamination, but clearly phase layered with the proportions of all 3 phases varying.
0-28 cm, olivine-gabbro: 5%-10% olivine, 55% plagioclase, 30% clinopyroxene.
62-96 cm, gabbro: 0%-5% olivine, 55%-75% plagioclase, 25%-40% clinopyroxene.
96-135 cm, olivine-gabbro: 5%-10% olivine, 55% plagioclase, 25%-40% clinopyroxene.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-75%.
Crystal size: 0.7-8 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 0.2-30 mm.
Crystal shape: Subophitic to oikocrystic.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 0%-20%.
Crystal size: 1-12 mm.
Crystal shape: Subophitic to oikocrystic.
Preferred orientation: None.
Percent replacement: Not determined.

Iron-oxides—Mode: 1%.
**SECONDARY MINERALOGY:**
Total percent: Variable, 3%.
Texture: Alteration is weak with local partial replacement and rimming of clinopyroxene and formation of some interstitial actinolite and chlorite(?). Olivine frequently appears to have a mesh network of iron-oxide (magnetite?) running through it.
Percent vein material: <1%.
Vein material: Actinolite, plagioclase, and green talc or chlorite. One alteration vein occurs in Piece 1C and contains actinolite, plagioclase, and green talc or chlorite.
**COMMENTS:** Equigranular gabbro with ophitic to subophitic texture. 1 cm euhedral to subhedral plagioclase laths are enclosed in oikocrysts of intergrannular clinopyroxene and olivine. Disseminated sulfides and oxides occur as inclusions in the olivine and pyroxene and interstitially between grains. Pyroxene oikocrysts 2-5 cm.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CORE/SECTION

118-735B-74R-3

**UNIT 5: OLIVINE-GABBRO**

**Pieces 1A-3F**

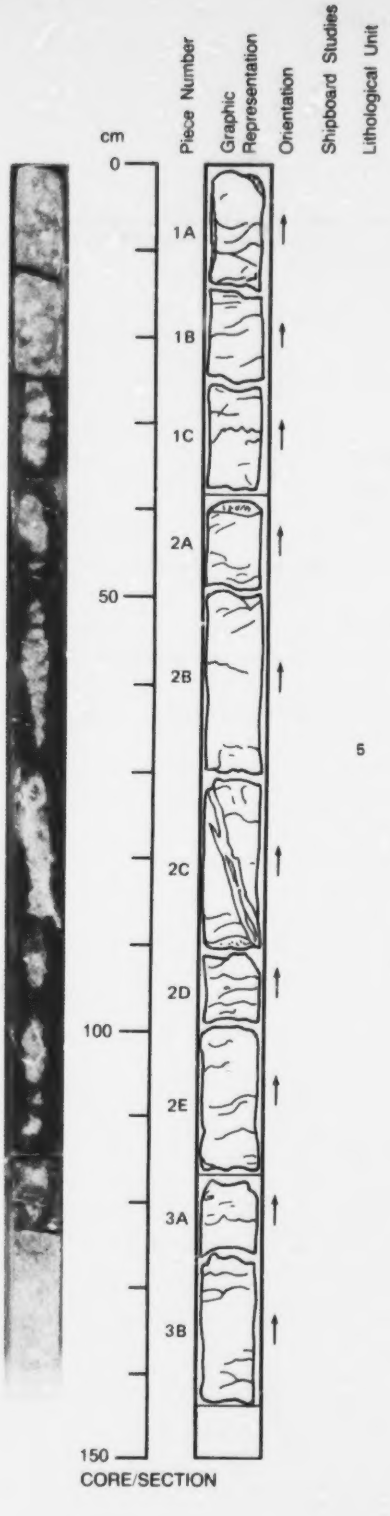
**Olivine Gabbro**

**Pieces 1A-3F**

**COLOR:** Gray.
**LAYERING:** None discernable. Most of core is coarse grained. A slightly medium-grained interval at 64-74 cm. Olivine is abundant throughout. It is difficult to discern any olivine-layered structure from the patchy, heterogeneous distribution of olivine.
**DEFORMATION:** None. A few brittle fractures.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-40%.
Crystal size: 2-10 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-40%.
Crystal size: 4-10 mm.
Crystal shape: Anhedral ophitic to poikilitic.
Preferred orientation: None.
Percent replacement: Minor amphibolitization.

Olivine—Mode: 5%-20%.
Crystal size: 3-12 mm.
Crystal shape: Anhedral, intergrown with plagioclase, rarely near subhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Minor.
Texture: Olivine altered to a mesh of tremolite-talc magnetite. Minor amphibolitization of clinopyroxene. A trace of sulfide.
Percent vein material: Not determined.
Vein material: A few small feldspathic veinlets, subhorizontal throughout.



**118-735B-74R-4**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3B**

**Olivine Gabbro**

**Pieces 1A-3B**

**COLOR:** Greenish gray with bronze luster for the huge oikocrysts.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**

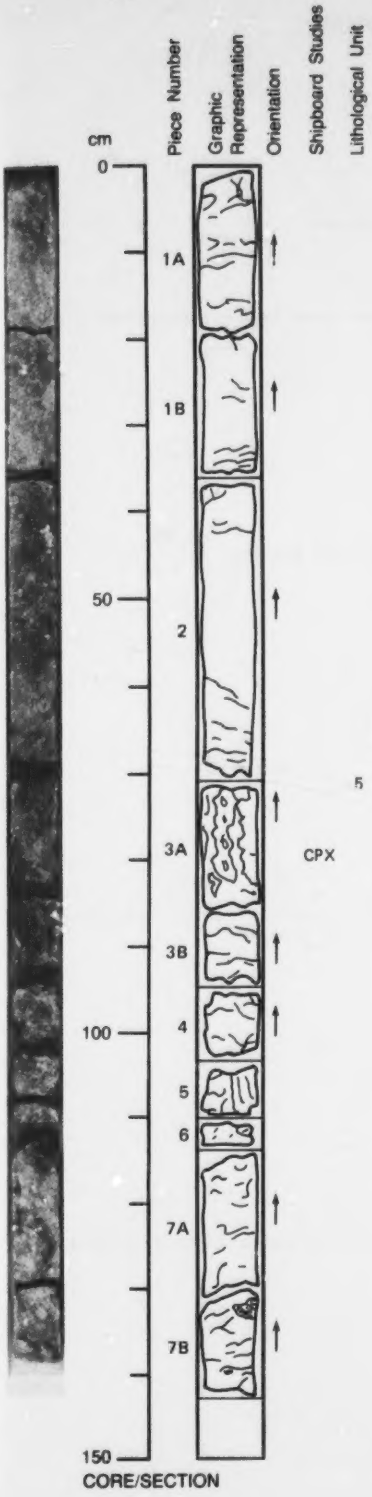
Plagioclase—Mode: 50%-60%.
Crystal size: 1-8 mm.
Crystal shape: Euhedral when included in clinopyroxene to anhedral interstitial.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-16 mm.
Crystal shape: Oikocrystic, enclosing euhedral plagioclase.
Preferred orientation: None.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 1-11 mm.
Crystal shape: Subhedral to rounded interstitial.
Preferred orientation: None.
Percent replacement: 30% replaced by talc, tremolite, magnetite, and clays.

**SECONDARY MINERALOGY:**

Total percent: 5% or less.
Texture: Coronitic. Olivine is partly altered into a mixture of talc, tremolite, magnetite, and brown clays (30% replacement). Clinopyroxene is partly replaced by green amphibole (pseudomorphs) particularly close to a vein in Piece 2C. Sulfides are present (<0.5 mm) in Pieces 1A, 2A, 2B, 2C, and 2E.
Percent vein material: Not determined.
Vein material: Amphibole. Vein in Piece 2C, 7-11 mm thick, plagioclase close to the walls (2-4 mm) and green amphibole in the center. Cracks are filled with light green amphibole.



## 118-735B-74R-5

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-7B**

**Olivine Gabbro (with Large Clinopyroxene Oikocrysts).**

**Pieces 1A-7B**

**COLOR:** Gray to grayish green.
**LAYERING:** Not present.
**DEFORMATION:** Not present.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 1-80 mm.
Crystal shape: Oikocrystic, subhedral.
Preferred orientation: Oikocryst is subvertical.
Percent replacement: <20% altered to green amphibole (more severely altered in Pieces 4, 5, 6, and top of Piece 7A).

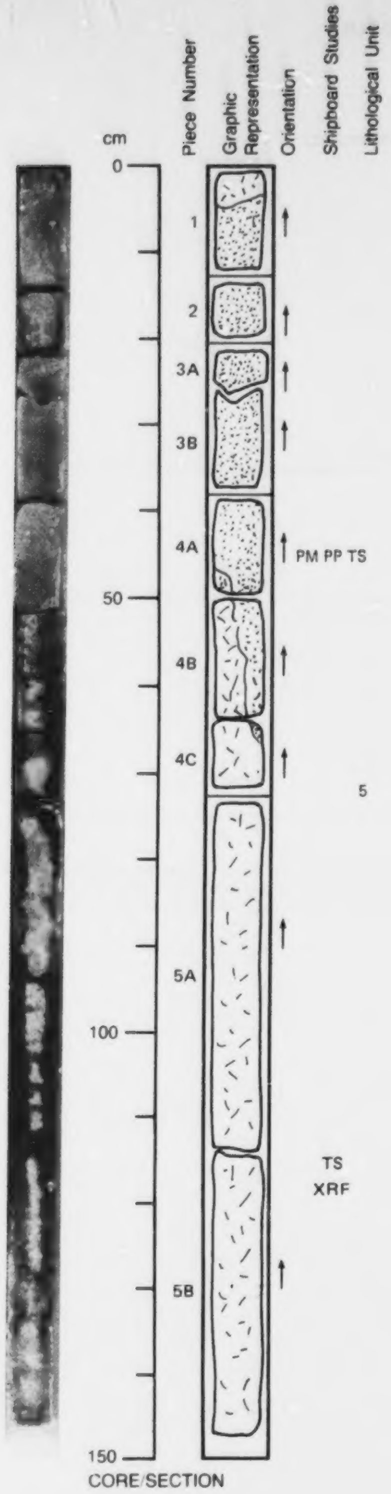
Olivine—Mode: 10%-15%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 10%-20% replaced by a mixture of tremolite-magnetite-talc-clays. Amphibole needles can be seen within olivine grains.

Ilmenite—Mode: Trace-2%.
Crystal size: (Piece 5) 2-4 mm.
Crystal shape: Granular.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: About 25%.
Texture: Coronitic, pseudomorphic.
Percent vein material: Not determined.
Vein material: Amphibole and clays. Late subhorizontal cracks (<1 mm) are filled with pale green amphiboles and gray clays.

**COMMENTS:** Sulfides: There are large intergrowths (up to 5 mm across) or isolated pentlandite (pinkish color) and chalcopyrite. They are 0.1-5 mm, irregular or molted, and are interstitial to silicate grains. Sometimes they are included in olivine or clinopyroxene (see Piece 3A).



**118-735B-74R-6**

## UNIT 5: OLIVINE GABBRO

### Pieces 1-5B

### Olivine-Bearing Diabase

### Pieces 1 (bottom)-4C

**COLOR:** Gray with light brown spots.
**LAYERING:** None. Equigranular texture, medium-grained.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral; orthopyroxene and opaques appear to be subophitically enclosing plagioclase.
Preferred orientation: None.
Percent replacement: 0%.

Clinopyroxene—Mode: 34%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%.

Orthopyroxene—Mode: 10%.
Crystal shape: Anhedral.
Crystal size: Individual grains <0.5 mm but brown spots 5 mm.
Preferred orientation: None.
Percent replacement: 0%.

Ilmenite—Mode: Near 1%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%.

Sulfides: Mode: Near 1%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 0%.
**SECONDARY MINERALOGY:**
Total percent: <1%.
Texture: Almost totally fresh.
Percent vein material: 0%.
Vein material: None.
**COMMENTS:** Contacts between diabase (microgabbro) and gabbro preserved in Piece 1, where it is nearly horizontal, and in Pieces 4A-C where it is nearly vertical.

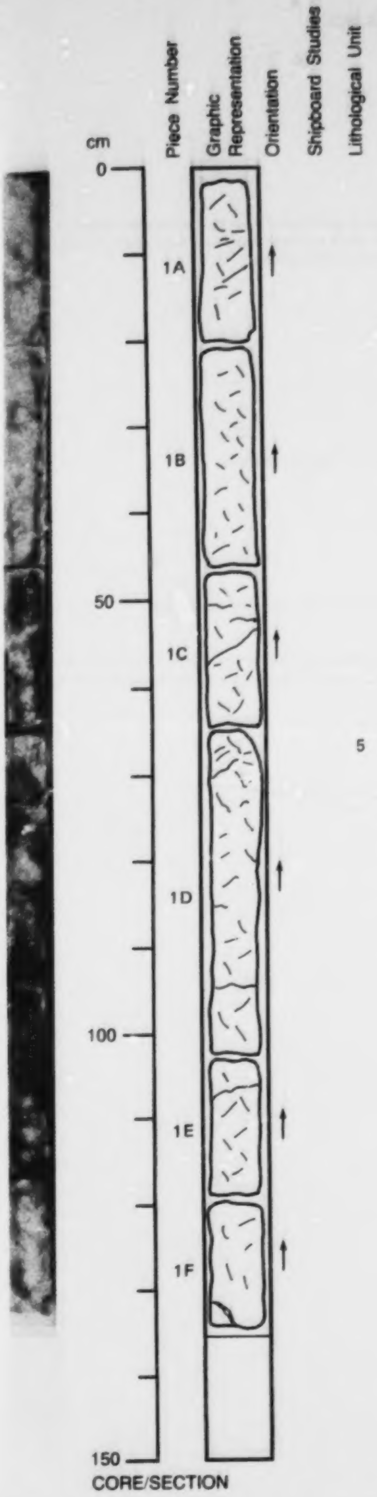
### Olivine Gabbro

### Pieces 1 (top) and 4A-5B

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 5-25 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%-40%.
Crystal size: 5-80 mm oikocrysts; clinopyroxene forms very large oikocrysts enclosing subhedral to euhedral plagioclase.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <1%.
Texture: Secondary green amphibole.
Percent vein material: 0%.
Vein material: None.



## 118-735B-74R-7

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1F**

**Olivine Gabbro**

**Pieces 1A-1F**

**COLOR:** Gray.

**LAYERING:** None well-defined. Most of core is coarse-grained. Two very coarse intervals at 65-70 cm (also plagioclase-rich) and 95-105 cm.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-80%.
Crystal size: 2-20 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

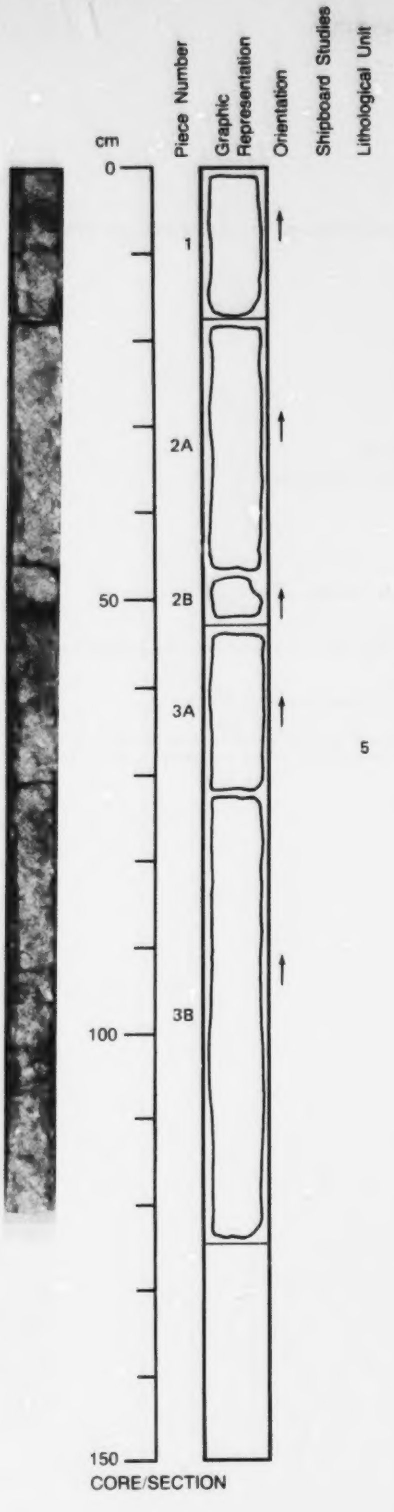
Clinopyroxene—Mode: 20%-40%.
Crystal size: 5-30 mm.
Crystal shape: Largely ophitic to poikilitic.
Preferred orientation: Not determined.
Percent replacement: Extensively amphibolitized in Piece 1F.

Olivine—Mode: 5%-20%.
Crystal size: 2-8 mm.
Crystal shape: Largely anhedral.
Preferred orientation: Not determined.
Percent replacement: Partly replaced by magnetite-talc-tremolite.

**SECONDARY MINERALOGY:**

Total percent: Slight. Core is quite fresh.
Texture: Clinopyroxene is extensively amphibolitized in Piece 1F. Olivine replaced in part by magnetite-talc-tremolite vein network.
Percent vein material: Not determined.
Vein material: One feldspathic vein cuts lower part of Piece 1F.

**COMMENTS:** Mineral distribution in coarse grained sections is irregular. There are 3-5 cm pods or sections of near troctolite and anorthositic gabbro, as well as olivine-poor and olivine-rich gabbro.



## 118-735B-75R-1

## UNIT 5: OLIVINE GABBRO

**Pieces 1-3B**

**Olivine Gabbro**

**Pieces 1-3B**

**COLOR:** Gray.

**LAYERING:** Primary layering defined by variations in grain size. Grain size varies over length of core. From 0-17 cm, very coarse-grained; from 17-42 cm, coarse-grained; from 42-74 cm, very coarse-grained; and from 74 cm to bottom back to coarse-grained.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

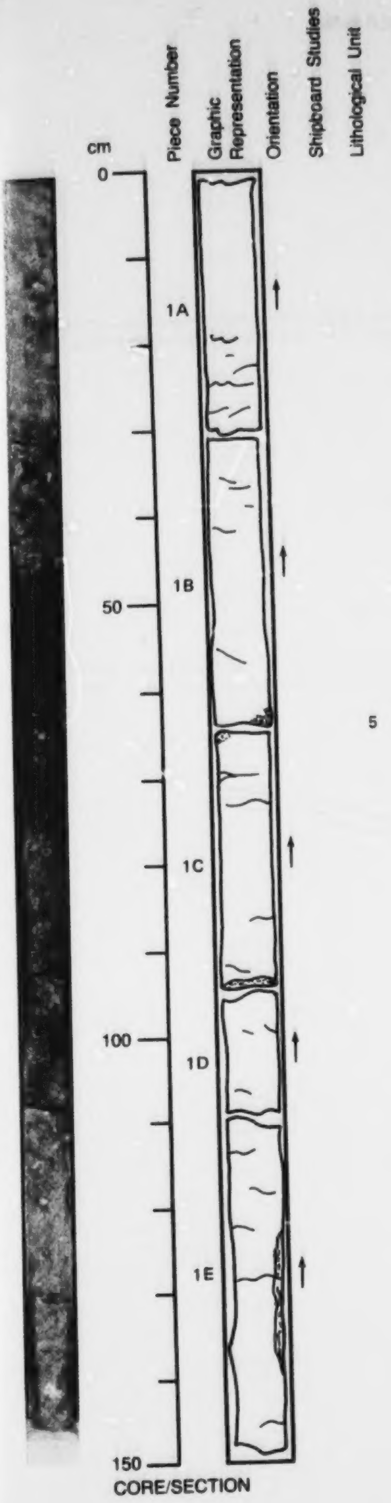
Plagioclase—Mode: 45%.
Crystal size: 1-3 cm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: 1%.

Clinopyroxene—Mode: 35%-40%.
Crystal size: 1-3 cm.
Crystal shape: Subhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 1% by amphibole.

Olivine—Mode: 15%-20%.
Crystal size: 0.7-1.8 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 15% by clay minerals or serpentine and iron-oxides.

**SECONDARY MINERALOGY:**

Total percent: 5%.
Texture: Amphibole partially replaces clinopyroxene. Traces of sulfides throughout. Olivine partially altered in meshlike fashion; mesh made of black mineral, maybe mixture of clay minerals or serpentine and iron-oxides.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1C
1D
1E
5
CORE/SECTION

**118-735B-75R-2**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1E**

**Olivine Gabbro**

**Pieces 1A-1E**

**COLOR:** Gray.
**LAYERING:** Not present.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-15 mm.
Crystal shape: Prismatic up to 2 cm long and included in large clinopyroxene oikocrysts that enclose both silicate phases. Arrangement is subophitic.
Preferred orientation: None.
Percent replacement: None.

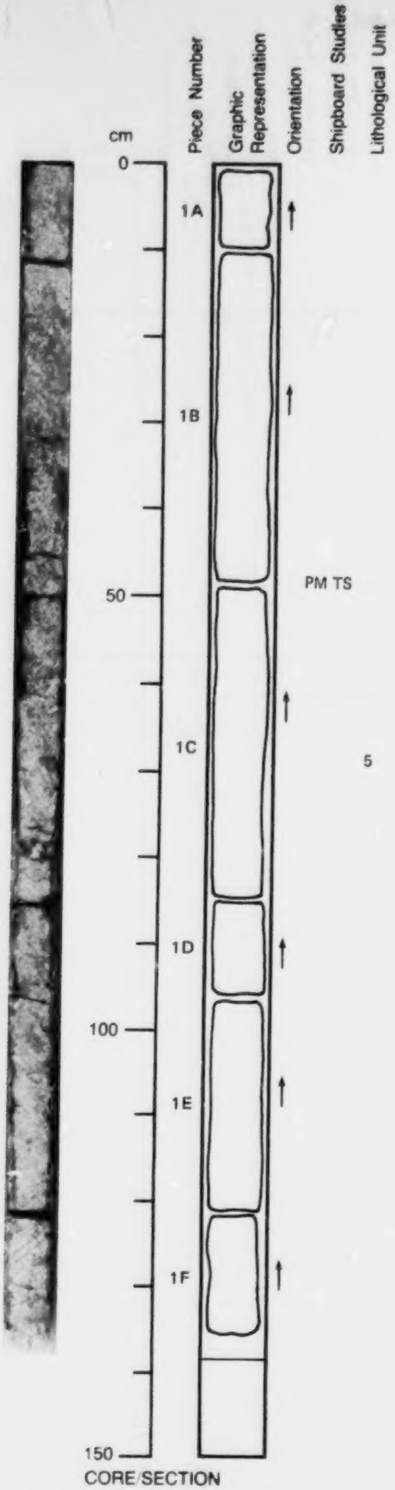
Clinopyroxene—Mode: 40%-50%.
Crystal size: 5-20 mm.
Crystal shape: Oikocrystic, anhedral.
Preferred orientation: None.
Percent replacement: <30% by green amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 1-5 mm.
Crystal shape: Rounded to irregular interstitial.
Preferred orientation: None.
Percent replacement: 20%-40% by actinolite, talc, and magnetite.

**SECONDARY MINERALOGY:**

Total percent: <20%.
Texture: Coronitic, pseudomorphic. Olivine is partly replaced by actinolite needles and talc with seams of magnetite. Clinopyroxene is partly transformed into green amphibole. Sulfides disseminated as small biebs <1.5 mm in interstitial spaces.
Percent vein material: Not determined.
Vein material: Late white cracks are filled with amphibole and clays (slightly sheared).

**118-735B-75R-3**


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1C
1D
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1F
PM TS
5
CORE/SECTION

### UNIT 5: OLIVINE GABBRO

**Pieces 1A-1F**

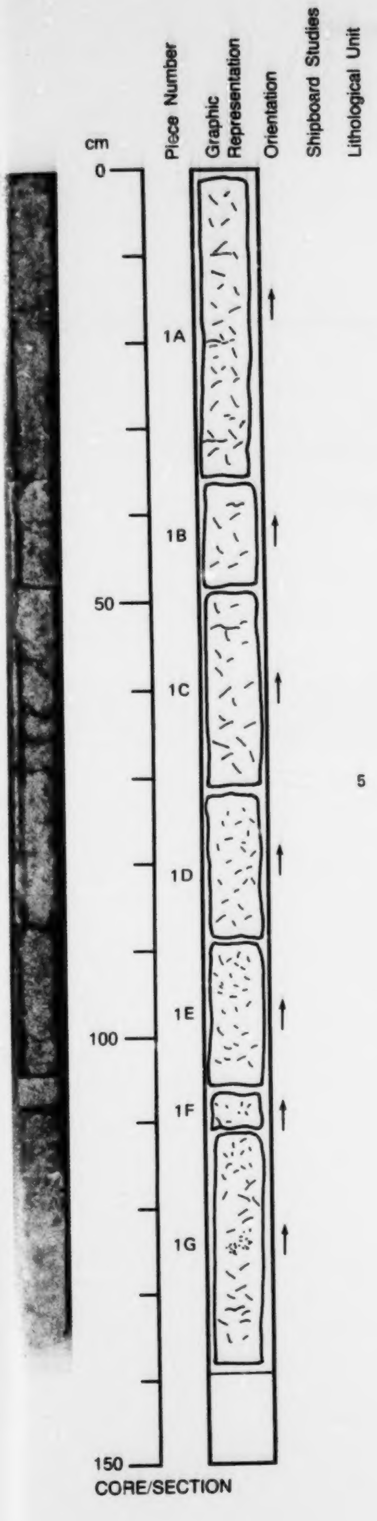
**Olivine Gabbro**

**Pieces 1A-1F**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral. Clinopyroxene subophitically encloses plagioclase, but plagioclase has a radiate arrangement as do the portions of clinopyroxene that partially enclose it, forming a flower or starburst pattern.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 40%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 1-2% by amphibole.

Olivine—Mode: 10%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 50% in mesh-like pattern.
**SECONDARY MINERALOGY:**
Total percent: 5-10%.
Texture: Olivine is altered in typical mesh-like fashion, but mesh seems to be more iron-oxide-rich than some previous sections. Minor alteration by amphibole (<5%-10%). Traces of sulfides.
Percent vein material: None.
Vein material: None.



### 118-735B-75R-4

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-1G**

**Olivine Gabbro**

**Pieces 1A-1G**

**COLOR:** Gray, green-gray where altered.

**LAYERING:** Olivine common throughout. Local concentrations of plagioclase and olivine, but no clear phase layering. Mostly coarse-grained, some coarse- to medium-grained intervals at 70-50 cm and 120-100 cm.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 40%-55%.
Crystal size: 2-13 mm.
Crystal shape: Euhedral-anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

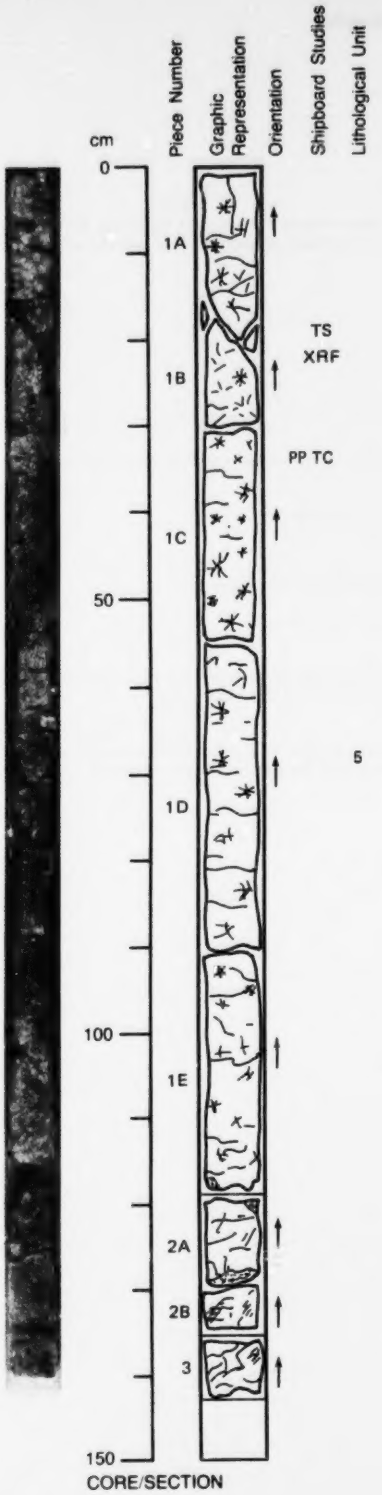
Clinopyroxene—Mode: 45%-50%.
Crystal size: 2-20 mm.
Crystal shape: Subhedral-anhedral, ophitic. Complex intergrowths with plagioclase in finer-grained section at 115-120 cm.
Preferred orientation: Not determined.
Percent replacement: Locally 5%-10% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral. In places intergrown with plagioclase.
Preferred orientation: Not determined.
Percent replacement: Up to 20% by magnetite-talc-tremolite.

**SECONDARY MINERALOGY:**

Total percent: Locally 5%-10%.
Texture: Olivine veined with dark mesh of magnetite-talc-tremolite. Much of section has a slight greenish cast, probably from amphibolitization of clinopyroxene.
Percent vein material: Not determined.
Vein material: Magnetite-talc-tremolite.

**COMMENTS:** There is a common (though < 1%) apparently primary sulfide in 1-2 mm, anhedral (in rare cases spherical) grains. Tentatively identified as pentlandite/chalcopyrite mixture.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
2A
2B
3
TS
XRF
PP TC
5
CORE/SECTION

**118-735B-75R-5**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3**

**Olivine Gabbro**

**Pieces 1A-3**

**COLOR:** Gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**

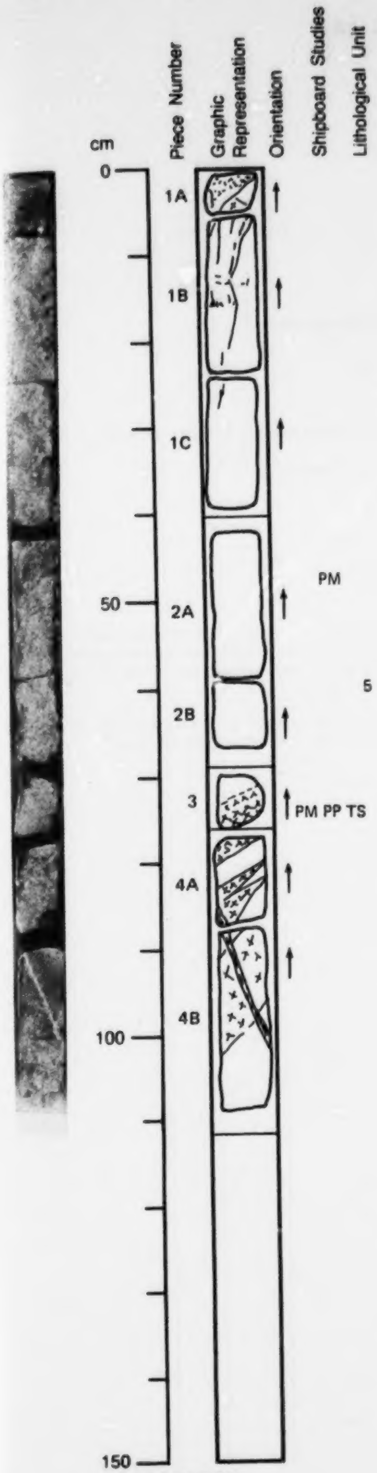
Plagioclase—Mode: 55%-65%.
Crystal size: 1-4 mm.
Crystal shape: Radiately included in clinopyroxene ("daisy" texture). Some plagioclase occurs also in the groundmass.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 35%-45%.
Crystal size: 1-2 cm.
Crystal shape: Oikocrysts that are on average 8 mm across are actually floating in plagioclase-rich groundmass.
Preferred orientation: None.
Percent replacement: <20%-30% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: None, except in Pieces 1A and 3 where olivine is replaced by clays, talc, and magnetite.

**SECONDARY MINERALOGY:**

Total percent: <10%.
Texture: Pseudomorphic. Olivine is very fresh except in Pieces 3 and 1A where it is altered to a mixture of brown clays, talc, and magnetite. Clinopyroxene is also fresh; it is replaced partially (20-30%) by amphiboles close to subhorizontal cracks filled with amphiboles. Sulfides are widespread throughout the section as accessory phases. Identified phases are pentlandite and chalcopyrite.
Percent vein material: Not determined.
Vein material: Amphibole.



**118-735B-75R-6**

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-4B**

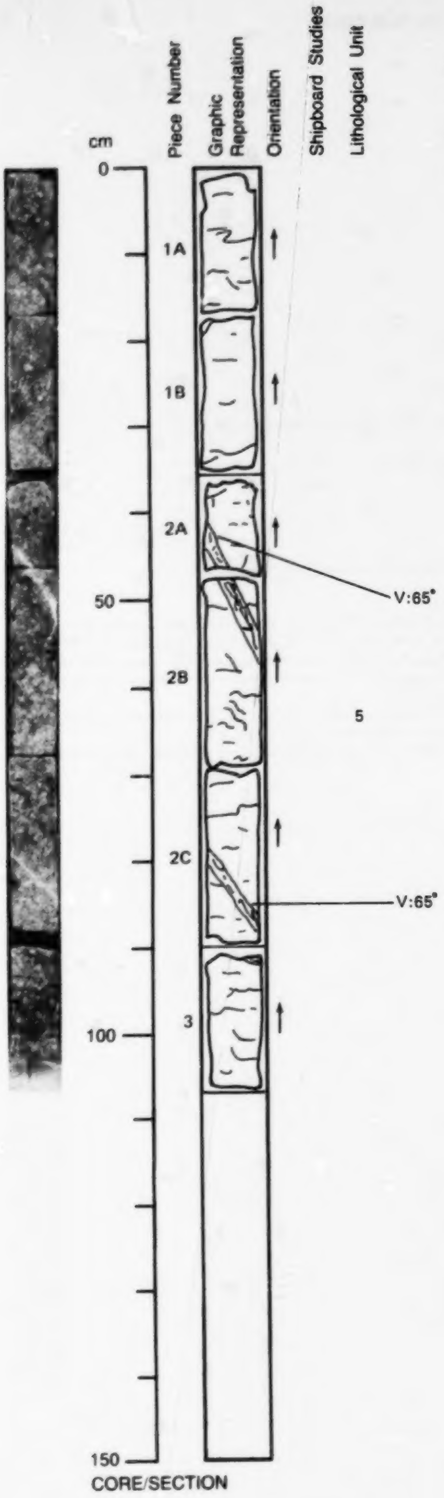
**Olivine Gabbro**

**Pieces 1A-4B**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: 4-9 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-45%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 30% by amphibole.

Olivine—Mode: 5%.
Crystal size: 3-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate replacement by talc and magnetite.
**SECONDARY MINERALOGY:**
Total percent: Moderate to slight.
Texture: Olivine is partly replaced by talc + magnetite. Clinopyroxene is partially altered to amphibole (30%) (20%-80% in Pieces 1A and 1B). The alteration is related to vein injection. Rare subhorizontal cracks are filled by amphibole (with little shearing). Traces of sulfides throughout the section; they fill intergranular spaces and some are related to vein injection.
Percent vein material: Not determined.
Vein material: In Pieces 1A and B, veins consist of plagioclase, (occassionally stained pinkish, apparently by iron-oxides) and green amphibole with acicular habit.
**COMMENTS:** Pieces 3, 4A, and 4B are diabase, i.e., medium-grained, but similar mineralogically to the surrounding olivine gabbro.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2A
2B
2C
3
V:65°
V:65°
5
CORE/SECTION

**118-735B-75R-7**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-3**

**Olivine Gabbro**

**Pieces 1A-3**

**COLOR:** Gray
**LAYERING:** Not apparent.
**DEFORMATION:** Not apparent.
**PRIMARY MINERALOGY:**

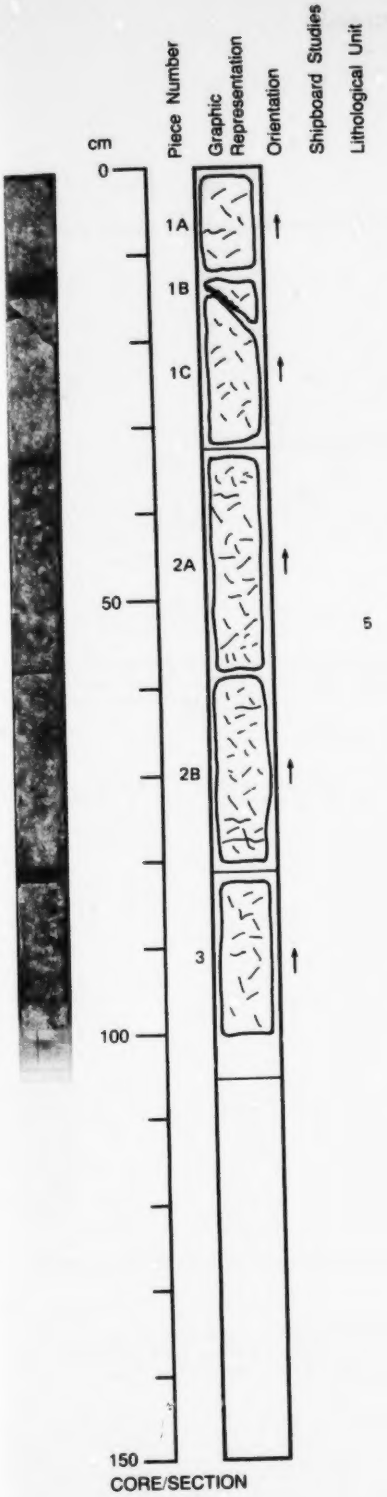
Plagioclase—Mode: 50%-60%.
Crystal size: 1-3 mm.
Crystal shape: Prismatic and included in clinopyroxene.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-15 mm.
Crystal shape: Oikocrystic type but of smaller grain size than the upper sections.
Preferred orientation: None.
Percent replacement: Slight replacement by amphibole.

Olivine—Mode: 10%.
Crystal size: 1-5 mm.
Crystal shape: Rounded.
Preferred orientation: None.
Percent replacement: 3% by talc and magnetite.

**SECONDARY MINERALOGY:**

Total percent: <1%.
Texture: Coronitic. Olivine is partly (3%) altered to talc + magnetite. Clinopyroxene is replaced by amphibole particularly where subhorizontal amphibole veinlets and subvertical plagioclase + amphibole veins cut the gabbro. Sulfides are widespread throughout the section as accessory interstitial phase (up to 1.5 mm across).
Percent vein material: Not determined.
Vein material: Amphibole and plagioclase. Steeply dipping veins (5-9 mm thick) are filled by plagioclase against the walls and amphibole in the center (Pieces 2A, 2B, and 2C).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
1A
1B
1C
2A
50
5
2B
3
100
150
CORE/SECTION

## 118-735B-75R-8

## UNIT 5: OLIVINE GABBRO

**Pieces 1A-3**

**Olivine Gabbro**

**Pieces 1A-3**

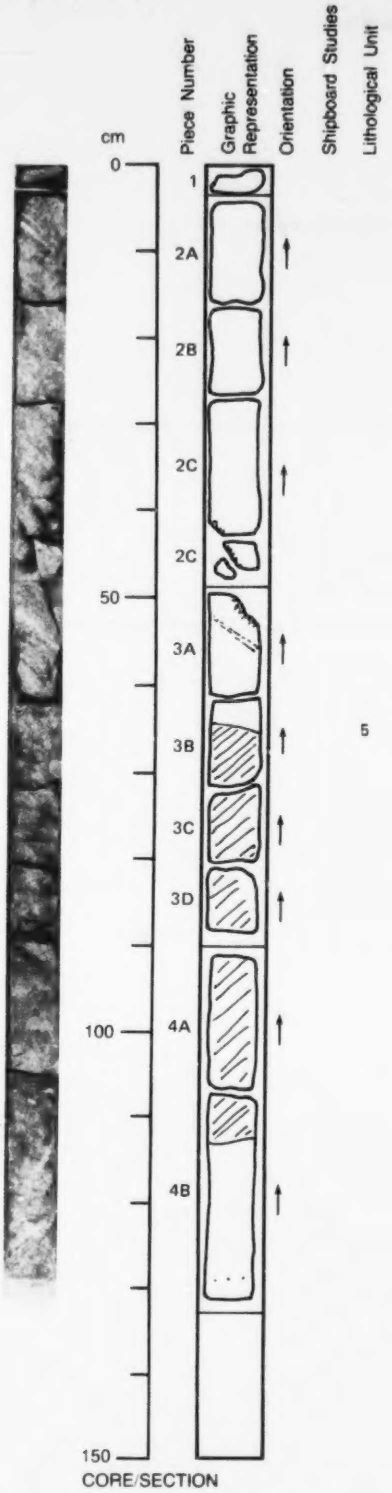
**COLOR:** Gray.
**LAYERING:** Coarse- to medium-grain transitions at 80-60 cm and 50-25 cm.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
- Plagioclase—Mode: 40%-60%.
- Crystal size: 3-20 mm.
- Crystal shape: Euhedral-anhedral.
- Preferred orientation: Not determined.
- Percent replacement: Not determined.

- Clinopyroxene—Mode: 20%-50%.
- Crystal size: 2-13 mm.
- Crystal shape: Subhedral-anhedral; ophitic at 0-11 cm and 80-100 cm; subhedral at 13-80 cm.
- Preferred orientation: Not determined.
- Percent replacement: Not determined.

- Olivine—Mode: 10%-20%.
- Crystal size: 2-10 mm.
- Crystal shape: Anhedral.
- Preferred orientation: Not determined.
- Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
- Total percent: Slight.
- Texture: Some mesh alteration (opaque/tremolite) in olivine. Plagioclase is pretty fresh as is clinopyroxene.
- Percent vein material: Not determined.
- Vein material: 1-2 mm thick feldspathic vein at 15 cm along a fracture. Several small subhorizontal feldspathic veins (<1 mm wide, 2-3 cm long) throughout.

**COMMENTS:** Trace sulfides.



**118-735B-76R-1**

## UNIT 5: OLIVINE GABBRO

**Pieces 1-4B**

### Olivine Gabbro

**Pieces 1-3B and 4B**

**COLOR:** Gray.
**LAYERING:** Primary layering defined by change in mineral assemblage between olivine and ilmenite gabbro.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 7-15 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: <1%.

Clinopyroxene—Mode: 49%-45%.
Crystal size: 5-30 mm.
Crystal shape: Anhedral, subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: <1%.

Olivine—Mode: 1%-5%.
Crystal size: 5-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 5%.

**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Fracture surface on outside of Pieces 2C and 3A coated with chlorite. Grain boundaries and thin veins filled by actinolite. Larger vein in Piece 3A filled by plagioclase, actinolite, and zoisite (pink). Numerous, nearly horizontal veinlets filled by white minerals.
Percent vein material: Not determined.
Vein material: Actinolite, Na-plagioclase, and zoisite.

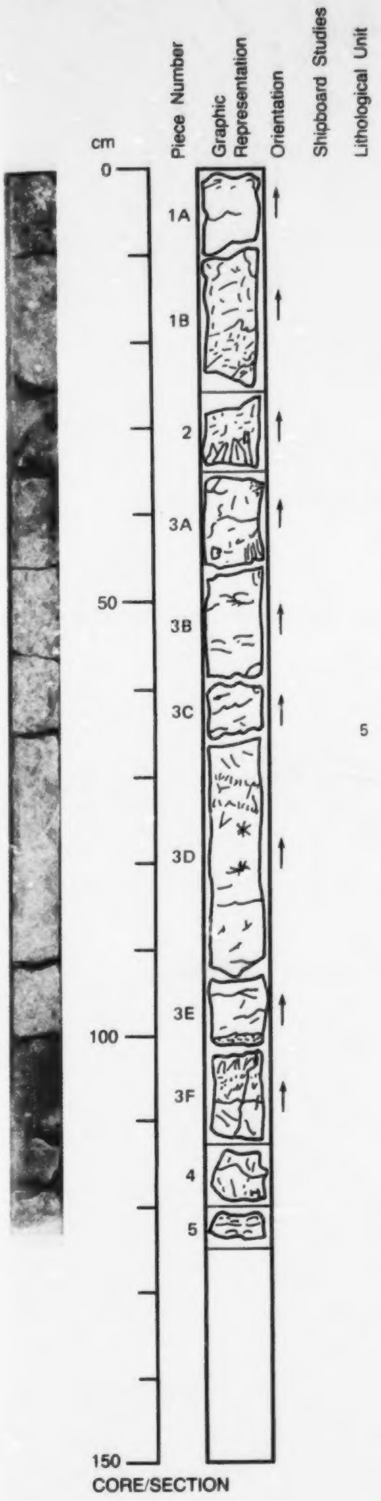
### Ilmenite Gabbro

**Pieces 3B-4B**

**COLOR:** Gray.
**LAYERING:** See above.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 95%-30%.
Crystal size: 1.5->5 cm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: <1% by amphibole.

Clinopyroxene—Mode: 5%-70%.
Crystal size: 1->4.5 cm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: <5% by amphibole.

Ilmenite—Mode: 1%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Green amphibole replaces along grain boundaries and thin veinlets. Trace of altered olivine.
Percent vein material: Not determined.
Vein material: Green amphibole
**COMMENTS:** Texture is obviously cumulus with cumulus plagioclase crystals touching and intercumulus clinopyroxene at the bottom of the ilmenite gabbro unit. Modal proportions extremely variable, but may be a function of large grain size relative to size of core.



118-735B-76R-2

## UNIT 6: OLIVINE GABBRO

**Pieces 1A-5**

**Olivine Gabbro (Alternating Fine- to Coarse-Grained Sub-Types).**

**Pieces 1A-5**

**COLOR:** Gray

**LAYERING:** Grain size contact in Pieces 1B, 1C, 2A, 2D, and 3F.

No inference is here made on the origin of the layers. There is an abrupt grain size change: coarse-grained gabbro, 1.5-2 cm; fine-grained gabbro, 1-3 mm. Layers are 5 mm to 9 cm thick in fine-grained gabbro. Some pyroxene crystals are nearly perpendicular to the contacts.

**DEFORMATION:** Not present.

**PRIMARY MINERALOGY:**

Plagioclase--Mode: 50% (coarse-grained gabbro), 60%-70% (fine-grained gabbro).
Crystal size: 1-5 mm (coarse-grained gabbro), 1 mm (fine-grained gabbro).
Crystal shape: Euhedral (coarse-grained gabbro).
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 40% (coarse-grained gabbro), 20%-30% (fine-grained gabbro).
Crystal size: 2-7 mm (coarse-grained gabbro), 1 mm (fine-grained gabbro).
Crystal shape: Oikocrystic and prismatic (coarse-grained gabbro, rarely Piece 1).
Preferred orientation: Not clear.
Percent replacement: 10%-20% by amphibole.

Olivine—Mode: 5%-10% (coarse-grained gabbro), 5%-10% (fine-grained gabbro).
Crystal size: 1-3 mm (coarse-grained gabbro), 1 mm (fine-grained gabbro).
Crystal shape: Anhedral, rounded.
Preferred orientation: None.
Percent replacement: 20% by chlorite or serpentine and magnetite.

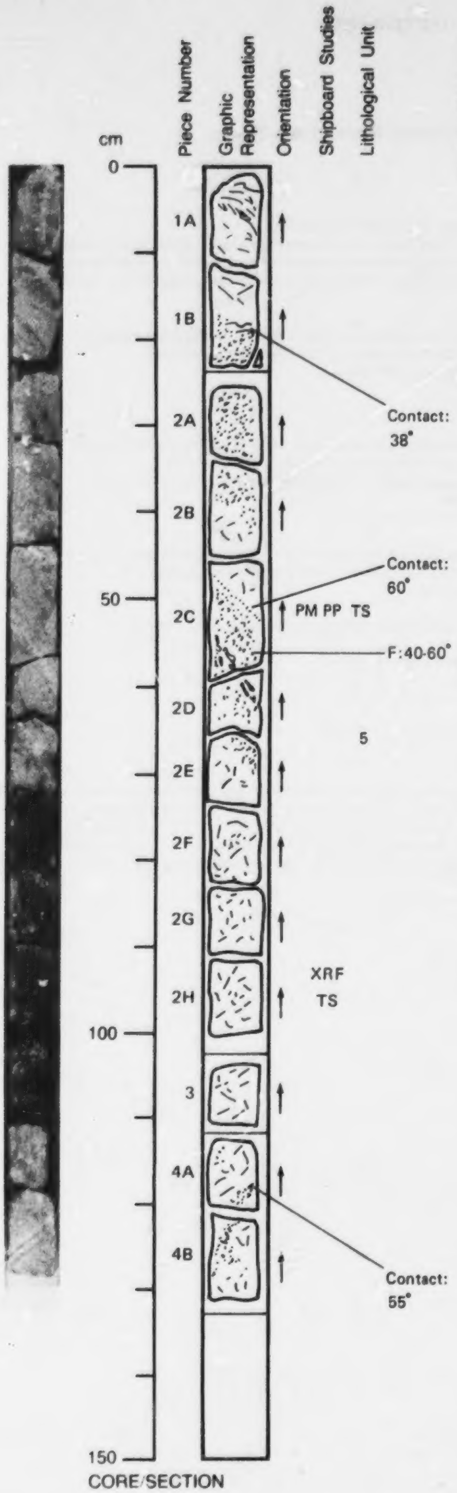
Ilmenite—(present in Piece 5) Mode: 3%-5%.
Crystal size: Not determined.
Crystal shape: Granular.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: <5%.

Texture: Coronitic. Olivine is partly replaced by dark chlorite or serpentine with magnetite making a web texture. Some brown clays are present. Clinopyroxene is only partly recrystallized to amphibole. Sulfides are mainly pinkish pentlandite and yellow green chalcopyrite as blebs up to 1.5 mm; chalcopyrite is found filling small cracks in altered olivine. Piece 5 in particularly rich in chalcopyrite (strings) around amphibolitized clinopyroxene.

Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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100
150
1A
1B
2A
2B
2C
2D
2E
2F
2G
2H
3
4A
4B
Contact: 38°
Contact: 60°
PM PP TS
F:40-60°
5
XRF
TS
Contact: 55°
CORE/SECTION

**118-735B-76R-3**

**UNIT 6: OLIVINE GABBRO**

**Pieces 1A-4B**

**Diabase-Microgabbro**

**18-40, 50-55, 60-67, and 115-127 cm.**

**COLOR:** Gray.
**LAYERING:** No layering.
**DEFORMATION:** Small shear zone at 55-60 cm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-50%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: <1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 0%, but may not have been identified.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Oxide—Mode: 0%-10%. Highest in fine-grained portions above 70 cm. Fine grained portion in Piece 4 has little oxide.
Crystal size: <1 mm.
Crystal shape. Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: Extensive.
Texture: Extensive amphibolitization of upper fine grained portion.
Percent vein material: Not determined.
Vein material: Not determined.

## 118-735B-76R-3 (continued)

### Olivine Gabbro

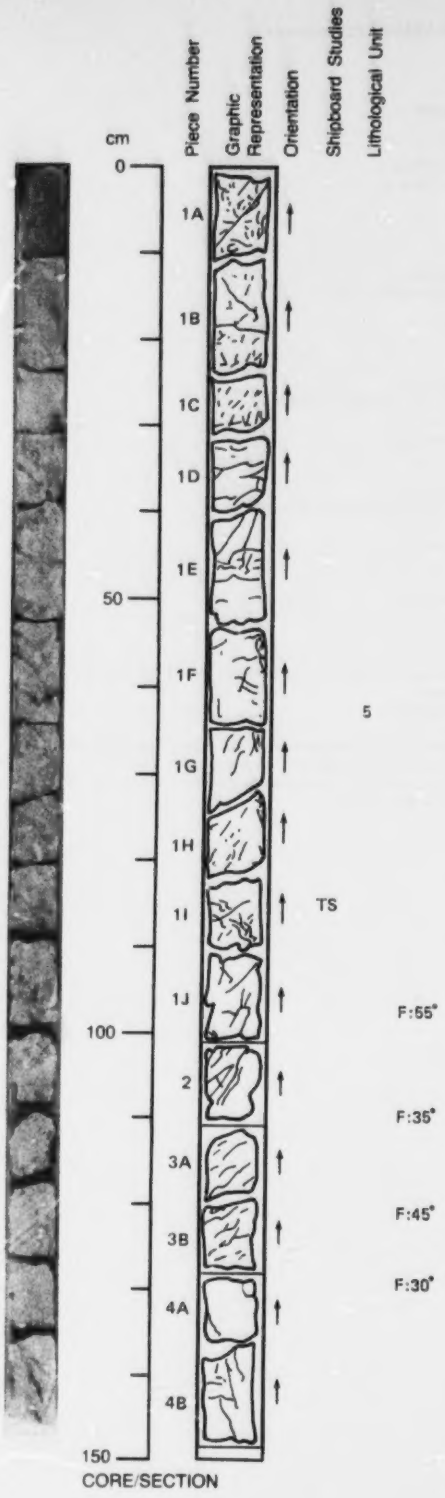
### 0-18, 40-50, 50-60, 67-114, and 127-132 cm

**COLOR:** Gray.
**LAYERING:** 1 small coarse to fine zone in Piece 1.
**DEFORMATION:** Weak foliation in top of Piece 1.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Locally by epidote in top.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Up to 40% by amphibole in Piece 1.

Olivine—Mode: 10% below 15 cm only.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: 20% altered to talc/magnetite.

Oxide—Mode: 5%-10% in top 15 cm only.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Up to 40%.
Texture: Piece 1A: epidote replacing plagioclase in part; Pieces 1A and 1B: extensive amphibolitization of clinopyroxene
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** The section is mixed gabbro with microgabbro lenses and layers. The oxides are described only in the top and may be associated with the deformation. The thin section description of Piece 2C, 50-52 cm, describes orthopyroxene oikocrysts associated with both the coarse and fine portions near the contact.



**118-735B-76R-4**

**UNIT 5: OLIVINE GABBRO**

**Pieces 1A-4B.**

**Olivine Gabbro**

**Pieces 1A-4B.**

**COLOR:** Gray to greenish gray.

**LAYERING:** Planar or irregular contacts between coarse-grained and fine-grained gabbros. The grain size contrast is 1-2 cm to 1 mm. Fine-grained gabbro has subophitic texture coarse-grained gabbro has a more oikocrystic-type texture to interlocking texture. Plagioclase and clinopyroxene are elongated and up to 2.4 cm in length.

**DEFORMATION:** Shearing and porphyroclastic-type textures in Pieces 1E, 1I, 2, 3A, and 3B. The deformed bands at least 1 cm thick are locus of preferred replacement of clinopyroxene by green amphibole (on sawn surface) and injection of ilmenite blebs and lenses. Amphiboles are present also away (1-2 cm) from the main shear.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 1-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Yes.
Percent replacement: Not determined.

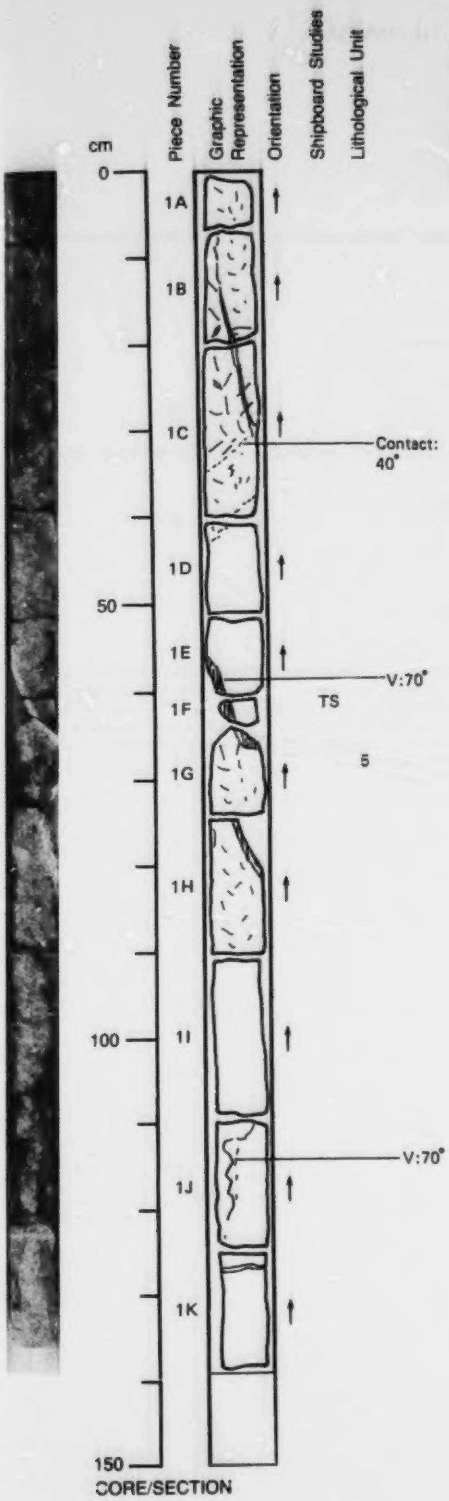
Clinopyroxene—Mode: 35%-50%.
Crystal size: 5-24 mm.
Crystal shape: Lens.
Preferred orientation: Not determined.
Percent replacement: 30% by amphibole.

Olivine—Mode: 5%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Severely altered to clays, chlorite, and magnetite.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Coronitic. Ilmenite bands are seen in Pieces 1E and 1I associated with amphibolitized clinopyroxene. Elsewhere clinopyroxene is slightly (30%) replaced by amphibole. Olivine is replaced by clays and chlorite mixture plus magnetite giving a web texture. Some iron hydroxides are also present. Sulfides are present in all coarse-grained gabbro. Individual blebs (up to 2 mm) and are composed of chalcopyrite and pentlandite. In the deformed gabbros calcite is present as 3 mm thick yellow brown to pink veins.
Percent vein material: Not determined.
Vein material: Calcite and sulfide.

## 118-735B-76R-5


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
1E
1F
1G
1H
1I
1J
1K
Contact: 40°
V:70°
TS
5
V:70°
CORE/SECTION

### UNIT 5: OLIVINE GABBRO

**Pieces 1A-1K**

**Olivine-Bearing Gabbro**

**Pieces 1A-1K**

**COLOR:** Gray.

**LAYERING:** Grainsize changes as follows: Pieces 1A-1B = coarse-grained; Pieces 1B-1C (top) = very coarse-grained (>4 cm); Piece 1C (bottom) = coarse-grained (1-1.5 cm); Pieces 1D-1F = medium-grained; Pieces 1G-1I = coarse-grained; Pieces 1J-1K = medium-grained (0.5-1 cm). Contacts are sharp between grainsize boundaries.

**DEFORMATION:** None.

**PRIMARY MINERALOGY:**

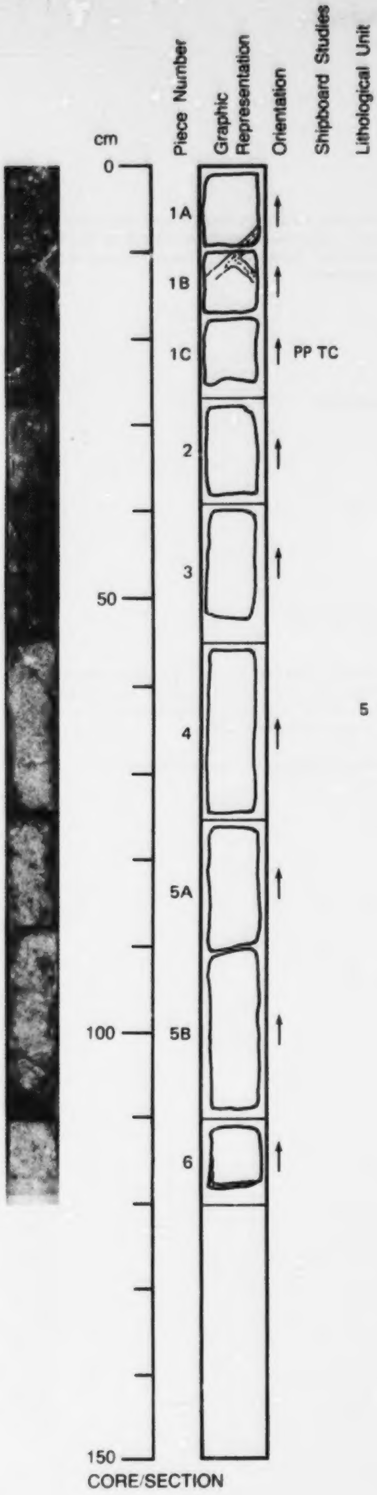
Plagioclase—Mode: 50%-60%.
Crystal size: 0.3-1 cm.
Crystal shape: Subhedral.
Preferred orientation: None apparent.
Percent replacement: 10% by sodic plagioclase.

Clinopyroxene—Mode: 35%-40%.
Crystal size: 0.3-4 cm.
Crystal shape: Subhedral to poikilitic.
Preferred orientation: None apparent.
Percent replacement: >10% by amphibole.

Olivine—Mode: 5%.
Crystal size: 0.3-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None apparent.
Percent replacement: 1%-2% by clay and iron-oxide.

**SECONDARY MINERALOGY:**

Total percent: >10%.
Texture: Piece 1D: oxidation of olivine. Pieces 1E-1H Vein >1 cm wide with amphibole on margin and pinkish silicate with white spherules on interior. Olivine near vein altered to clay stained with oxide. Vein of albite in Pieces 1B, 1C, and 1K (oriented 70°). Vein in 1J is paralle to core and is filled with amphibole. Few grains of sulfide present.
Percent vein material: Not determined.
Vein material: 10% albite; hornblende; albite-chlorite-actinolite-epidote-sphene.



## 118-735B-76R-6

### UNIT 5: OLIVINE GABBRO

**Pieces 1A-6**

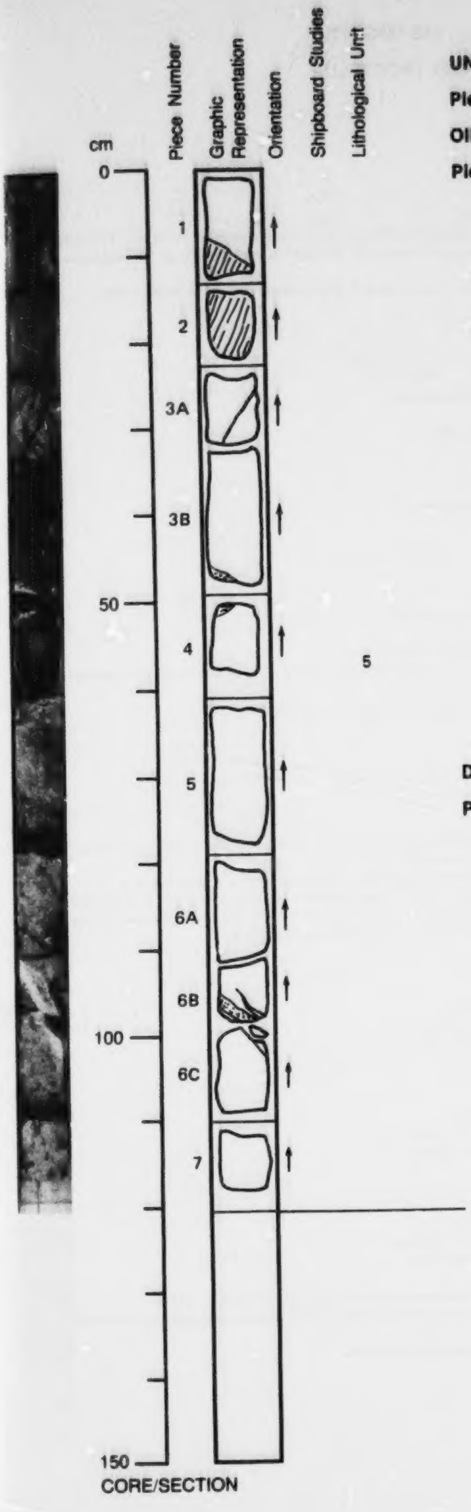
**Olivine Gabbro**

**Pieces 1A-6**

**COLOR:** Gray.
**LAYERING:** Difficult to tell. Between 28-54 cm grain shapes are more blocky and an obvious cumulus texture is produced.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 5-40 mm.
Crystal shape: Subhedral to euhedral.
Preferred orientation: None.
Percent replacement: 10%-15%.

Clinopyroxene—Mode: 37%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral. Between 0-27 cm and 60-120 cm clinopyroxene subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 10%-15%

Olivine—Mode: 2%-3%.
Crystal size: 2-7 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60%-70%.
**SECONDARY MINERALOGY:**
Total percent: <5-10%.
Texture: Amphibole occurs along grain margins and thin fractures throughout section. Veins in Pieces 1A and 1B are filled by plagioclase, epidote(?), and actinolite. Olivine altered along a mesh of fractures. Mesh is defined by black minerals(?) with a metallic luster, may be iron-oxides. In piece 5A, thin fractures filled by greenish-white minerals cross cut olivine. Where they cross cut, the greenish minerals disappear, and olivine is altered to pyrite or rather pyrite has crystallized locally along the fractures.
Percent vein material: Not determined.
Vein material: Plagioclase, epidote(?), actinolite, and pyrite.



## 118-735B-76R-7

### UNIT 5: OLIVINE GABBRO

**Pieces 1-7**

**Olivine Gabbro**

**Pieces 1 (top) and 3A-7**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 5-13 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 10-15%.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 7-13 mm.
Crystal shape: Subhedral. Single clinopyroxene oikocryst 4 cm long in Piece 7. Subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 10-15%.

Olivine—Mode: 10%-5%.
Crystal size: 3-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 60-70%.
**SECONDARY MINERALOGY:**
Total percent: Approximately 10%.
Texture: Alteration in Pieces 6A, 6B, and 7 consists of green amphibole along thin veins and wide alteration haloes of talc and tremolite and actinolite around olivine. Pieces 3A-3B, and 4: no alteration haloes around olivine and almost no secondary amphibole. Fragment of vein on Pieces 3B and 4 are plagioclase and actinolite as are veins in Pieces 6B and 6C.
Percent vein material: Not determined.
Vein material: Plagioclase and actinolite.

**Diabase**

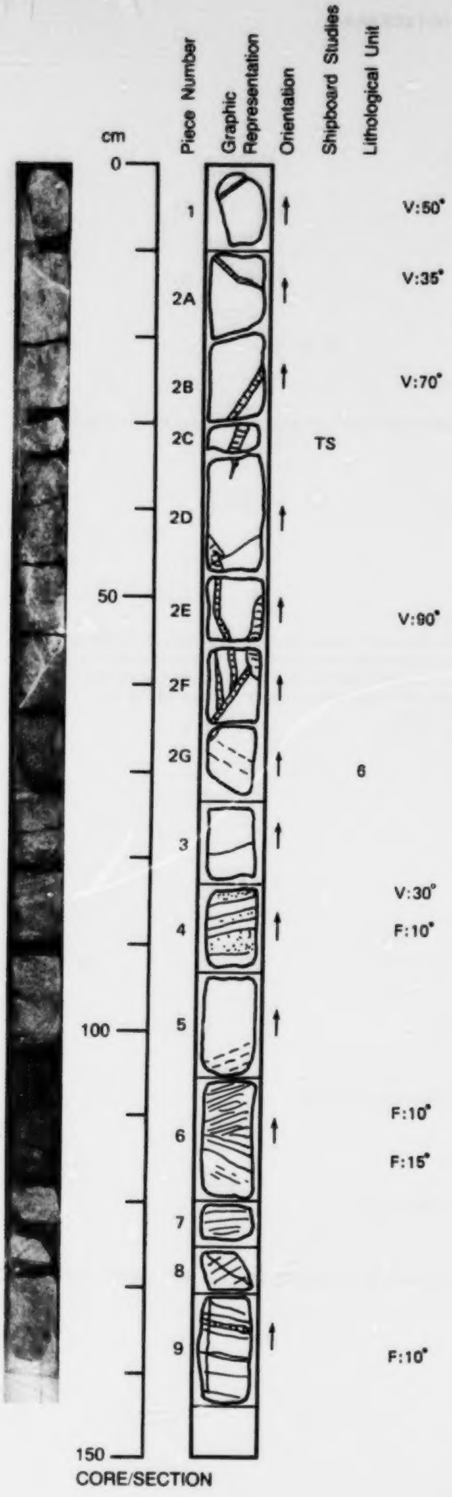
**Pieces 1 (bottom) and 2**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%-65%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 35%-30%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight alteration to amphibole.

Olivine—Mode: 5%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight to moderate.

**SECONDARY MINERALOGY:**
Total percent: Slight.
Texture: Clinopyroxene partially altered to amphibole. Olivine has same metallic coating on grains as gabbro.
Percent vein material: None.
Vein material: None.



118-735B-77R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-9

### Olivine Gabbro

### Pieces 1-3 (top)

**COLOR:** Gray with green-white veins.
**LAYERING:** Grain size variations: ≤0.8 cm in Piece 1; ≤1.5 cm in Piece 2A; ≤1 cm in Piece 2D; ≤0.5 cm in Piece 2F; ≤0.3 cm in Piece 2G; no obvious modal layering. No magmatic lamination.
**DEFORMATION:** None to very little in top of Piece 3. Slight cataclasis close to the veins.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: See layering.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-35%.
Crystal size: See layering.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 10%-20%.
Crystal size: See layering.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Slight except close to the veins.
Texture: Amphibole replaces clinopyroxene and olivine. Plagioclase is slightly albitized.
Percent vein material: 1%-5%.
Vein material: Amphibole ± sodic plagioclase ± sulfides.

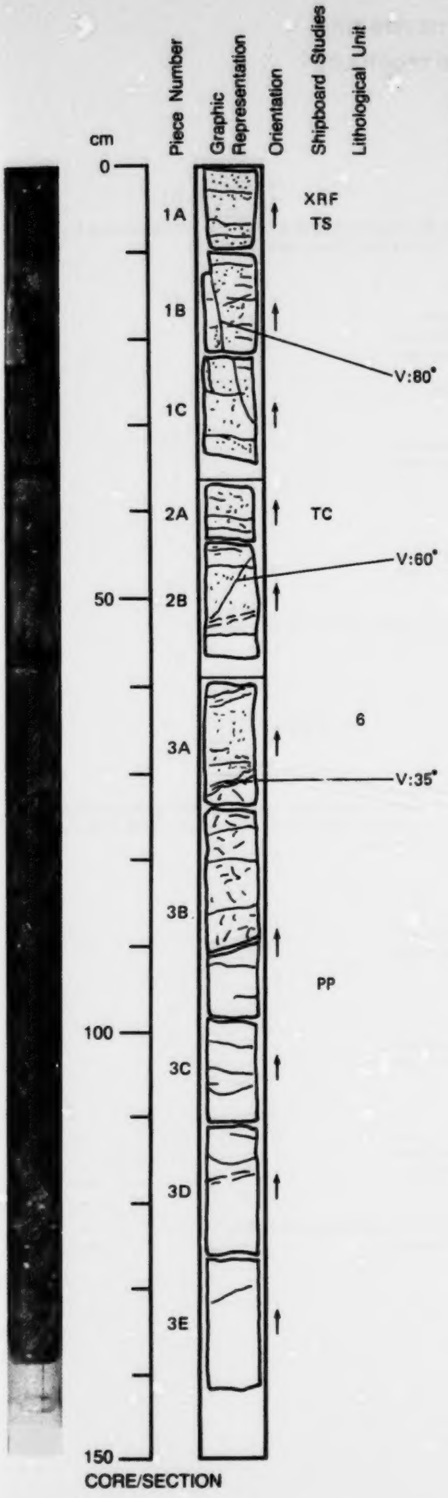
### Deformed Olivine Gabbro

### Pieces 3 (bottom) -9

**COLOR:** Gray.
**LAYERING:** Transposed by the plastic deformation but still visible in Piece 4: Original thickness of troctolitic layers cannot be evaluated.
**DEFORMATION:** The deformation textures range from poorly foliated in Pieces 3 and 5, to porphyroclastic in Pieces 4, 6, 7, and 8, and mylonitic in the top of Piece 6. This reflects a gradient of strain toward a mylonitic band in top of Piece 6; the mylonitic foliation lies at an angle to the porphyroclastic foliation at the bottom of Piece 6.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: <0.5 cm.
Crystal shape: Porphyroclastic.
Preferred orientation: Marks the foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 5%-35%.
Crystal size: <0.5 cm.
Crystal shape: Porphyroclastic.
Preferred orientation: Marks the foliation.
Percent replacement: Not determined.

Olivine—Mode: 10%-40%.
Crystal size: <0.5 cm.
Crystal shape: Porphyroclastic.
Preferred orientation: Marks the foliation.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Slight except close to amphibole veins in Pieces 3, 7, and 8.
Texture: Amphibole replaces clinopyroxene and olivine, plagioclase is slightly albitized.
Percent vein material: <1%.
Vein material: Amphibole ± sodic plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
2A
2B
3A
3B
3C
3D
3E
XRF
TS
TC
PP
6
V:80°
V:60°
V:35°
CORE/SECTION

**118-735B-77R-2**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-3E**

**Olivine Gabbro**

**Pieces 1A-3E**

**COLOR:** Dark to medium gray.

**LAYERING:** Defined by gradation in grain size and possibly by some variations in mineral proportions. Grain size variation as follows: 0-50 cm, fine-grained (<0.5 cm); 50-60 cm, medium-grained (0.5-1 cm); 60-70 cm, fine-grained (<0.5 cm); 70-90 cm, coarse-grained (2-3 cm); 90-115 cm, coarse-grained (1-2.5 cm); and 115-145 cm, coarse- to medium-grained (0.5-2 cm).

**DEFORMATION:** Slight deformation (foliation) in Pieces 1A, 1B, 1C, 2, and 3A, defined by mineral stretching. Pieces 3B-3E undeformed.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 0.4-3.0 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: <0.4-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

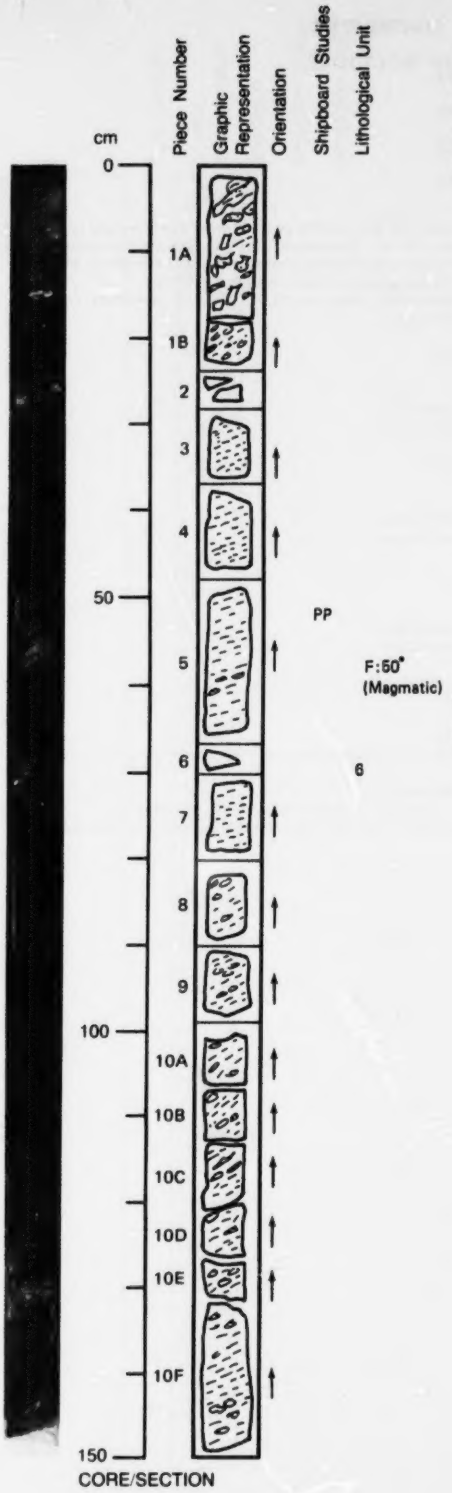
Olivine—Mode: 5%-20%.
Crystal size: <0.2-2.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 3%. Sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**

Total percent: Slight alteration.
Texture: Olivine relatively fresh. Some amphibole replacement of clinopyroxene (<10%), few sulfides(?).
Percent vein material: Not determined.
Vein material: Veinlets with amphibole + white mineral, mostly subhorizontal.

**COMMENTS:** Stippled portions fine-grained (<0.5 cm). White portions coarse- to medium-grained (1.0-2.5 cm).



**118-735B-77R-3**

**UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE**

**Pieces 1A-10F**

**Olivine Gabbro**

**Pieces 1A-2**

**COLOR:** Gray.
**LAYERING:** Igneous lamination defined by elongated plagioclase, olivine, and clinopyroxene.
**DEFORMATION:** Weak. Minerals have retained their primary igneous shapes.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-65%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Clinopyroxene and olivine partly replaced by amphibole.
Percent vein material: Not determined.
Vein material: Not determined.

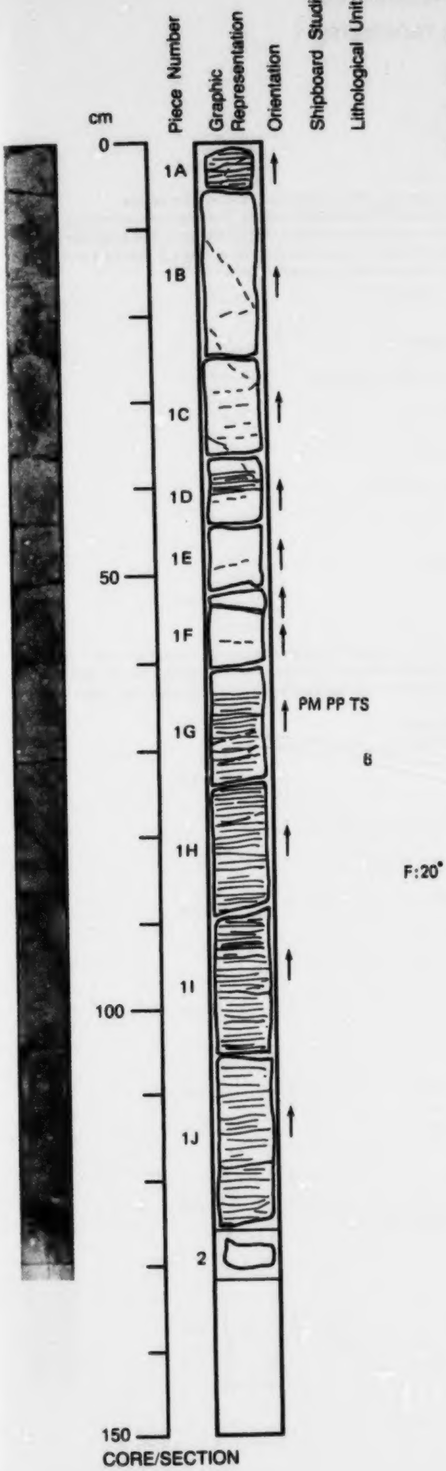
**Olivine Microgabbro**

**Pieces 3-10F**

**COLOR:** Gray.
**LAYERING:** Well-defined igneous lamination.
**DEFORMATION:** Arguably moderate as it accentuates igneous lamination. Clinopyroxene appears to retain igneous shape. Plagioclase likely has been recrystallized. Deformation of fine-grained crystal mush? Crystal growth under stress?
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 0.5-2 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: 0.5-2 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 20%.
Crystal size: 0.5-1 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Minor amphibole replacing clinopyroxene and olivine.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-77R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-2**

**Alternating Massive Gabbro and Foliated Metagabbro**

**Pieces 1A-2**

**COLOR:** Gray to very dark gray; speckled white/dark where coarse grained. Locally veined with green epidote.

**LAYERING:** Coarse/fine grain size variations where not foliated (Pieces 1B and 1C especially).

**DEFORMATION:** Intensely foliated, even mylonitized where shown by lined sections on column. Fractured parallel to foliation and roughly orthogonal to it (dashed lines). A vertical fracture runs parallel to the sawn surface through Pieces 1D-1H. Portions described as massive gabbro have much mineral orientation parallel to foliation. Foliation dip approximately 20° in Pieces 1G-1J. Locally porphyroclastic.

**PRIMARY MINERALOGY:**

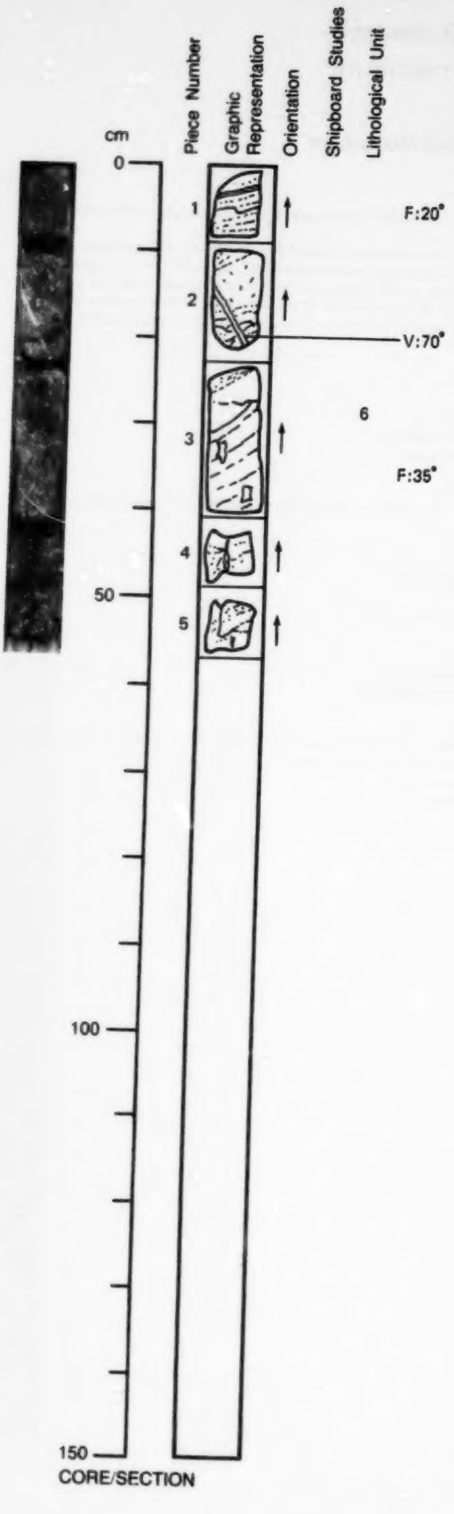
Plagioclase—Mode: 50%-60%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Parallel to foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-50%.
Crystal size: Very coarse clinopyroxene in Piece 1B (10-15 cm), Piece 1C (29-31 cm), and Piece 1F (55-60 cm).
Crystal shape: Not determined.
Preferred orientation: Parallel to foliation.
Percent replacement: Not determined.

Olivine—Mode: Up to 3% in Pieces 1D-1F.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight.
Texture: Slight amount of green amphibole in most pieces. Epidote in fracture in Piece 1B. Amphibole more pervasive at top of Pieces 1I and 1J.
Percent vein material: Not determined.
Vein material: Amphibole and epidote.



**118-735B-77R-5**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-5**

**Olivine Gabbro**

**Pieces 1-5**

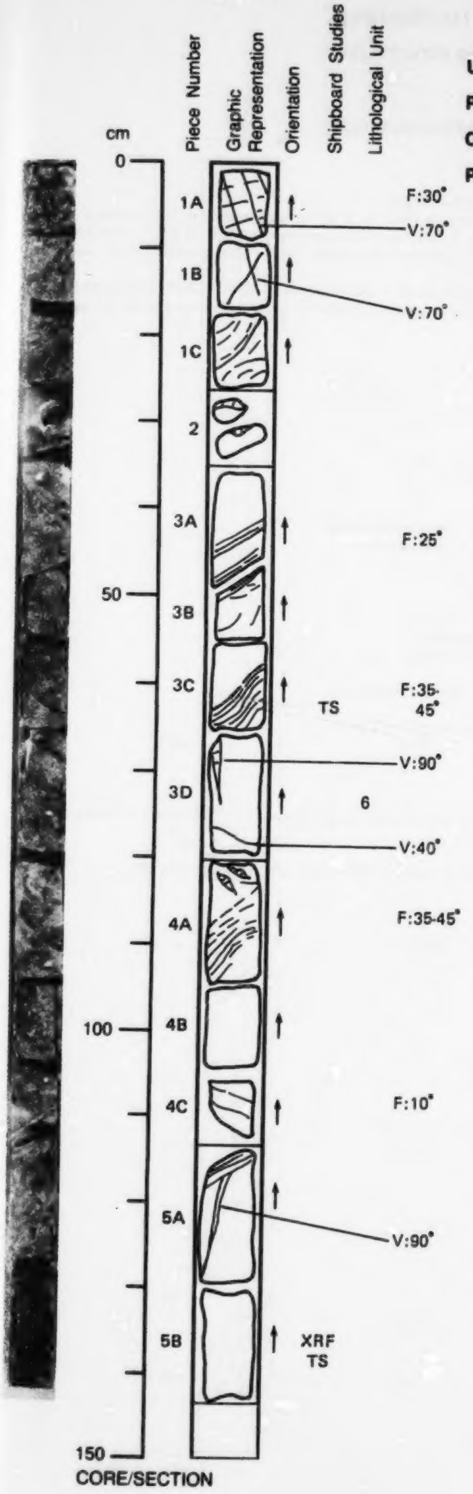
**COLOR:** Greenish-gray.
**LAYERING:** No magmatic, phase or size layering. Piece 1 has more olivine than others.
**DEFORMATION:** Foliation defined by flattened clinopyroxene crystals; elongate concentrations of opaques (Pieces 2 and 3) or bands and layers of recrystallized pyroxene and amphibole (Pieces 1, 4, and 5). Large porphyroclasts of pyroxene (2.5 cm) in Piece 3. Pieces 4 and 5 are finer grained (≤ 0.3 cm) and contain mylonitic to gneissic layers.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-55%.
Crystal size: 0.2-0.5 cm.
Crystal shape: Subhedral to elongate.
Preferred orientation: None.
Percent replacement: 5%-10% by sodic plagioclase.

Clinopyroxene—Mode: 20%-30%.
Crystal size: 0.3-2.5 cm.
Crystal shape: Anhedral to elongate.
Preferred orientation: None.
Percent replacement: ≥ 50% by amphibole.

Olivine—Mode: 10%.
Crystal size: ≤ 1 cm.
Crystal shape: Anhedral to elongate.
Preferred orientation: None.
Percent replacement: 1-2%.

**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Over half of clinopyroxene is replaced by green amphibole. Most extensive replacement is near large albite + amphibole vein (Piece 2) and in highly sheared rocks (Pieces 4 and 5). Veins all contain amphibole. Clinopyroxene or plagioclase near veins are replaced by dark chlorite.
Percent vein material: Not determined.
Vein material: Hornblende ± plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1A
1B
1C
2
3A
3B
3C
3D
4A
4B
4C
5A
5B
F:30°
V:70°
V:70°
F:25°
F:35-45°
TS
V:90°
6
V:40°
F:35-45°
F:10°
V:90°
XRF
TS

### 118-735B-78R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE.

### Pieces 1A-5B

### Olivine-Rich Gabbro with Local Shear Bands

### Pieces 1A-5B

**COLOR:** Gray.

**LAYERING:** No visible layering, but the olivine and plagioclase modal percents are not uniform. No magmatic foliation.

**DEFORMATION:** Constrained to 1.5 to 5 cm thick shear bands with augen gneissic or porphyroclastic textures. These bands develop preferentially in olivine-rich zones. Piece 1A: porphyroclastic texture; Piece 1C: porphyroclastic texture; bottom of Piece 3A and top of Piece 3B: porphyroclastic and augen greissic textures; bottom of Piece 3C: porphyroclastic and augen gneissic textures; Piece 4A: porphyroclastic and augen gneissic textures.

**PRIMARY MINERALOGY:**

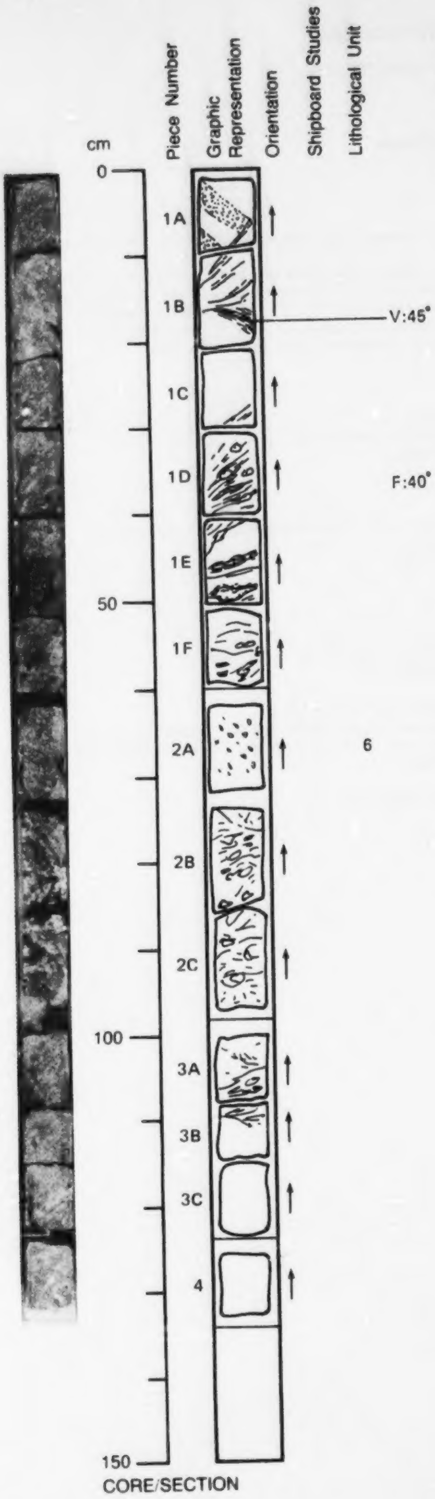
Plagioclase—Mode: 50%-60%.
Crystal size: <0.5-1.5 cm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Marks foliation in shear zones.
Percent replacement: Not determined.

Clinopyroxene—Mode: Not determined.
Crystal size: <0.5-1.5 cm.
Crystal shape: Euhedral-subhedral. Tends to enclose euhedral plagioclase crystals.
Preferred orientation: Marks foliation in shear zones.
Percent replacement: Not determined.

Olivine—Mode: 10%-25%.
Crystal size: <0.5-1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Marks foliation in shear zones.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight except close to the amphibole veins.
Texture: Amphibole replaces clinopyroxene and olivine; talc also replaces olivine. The plagioclase is albitized in Pieces 1A and 1B. In Pieces 4C and 5A, the amphibolitized zone is also very rich in iron-titanium oxides.
Percent vein material: <1%.
Vein material: Amphibole + sodic plagioclase.



**118-735B-78R-2**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-4**

### Olivine Gabbro Partly Deformed and Metamorphosed

**Pieces 1A-4**

**COLOR:** Gray, grayish green where amphibolitized.

**LAYERING:** Size variation shows layering. In Piece 1A, 2 cm thick alternation of fine-, (average 1-2 mm), and medium-grained (average 3-7 mm) layers are present. Grain size of other undeformed portions shows wide variation from coarse- (average 10-15 mm) to medium-grained (average 5-10 mm).

**DEFORMATION:** Prophyroclastic-mylonitic zones occur in Pieces 1B, 1C-1D, 1E-1F, 2B-2C, and 3A-3B. In Pieces 2B-2C, amphibolitization is extensive. Foliation varies from horizontal to 45°, but is generally 40°.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: See above.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: None.

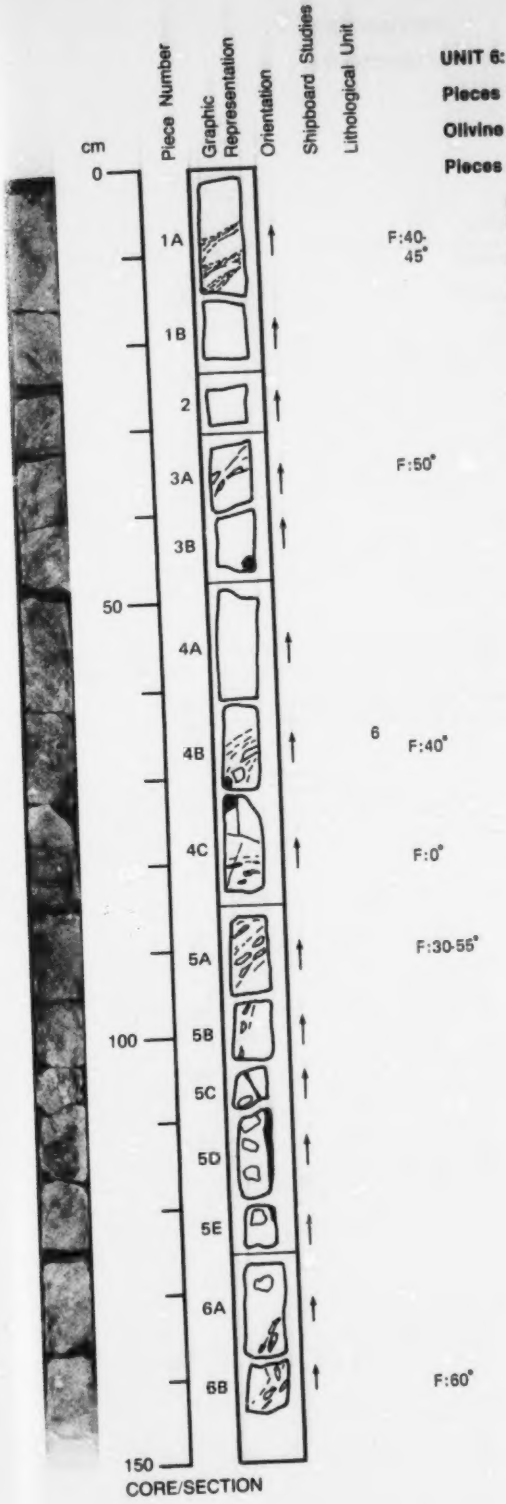
Clinopyroxene—Mode: 25%-35%.
Crystal size: See above.
Crystal shape: Anhedral.
Preferred orientation: None in undeformed portion.
Percent replacement: <10% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: See above.
Crystal shape: Anhedral.
Preferred orientation: None apparent.
Percent replacement: Not determined.

Fe-Ti oxide—Mode: 1%-5%, locally concentrated.
Crystal size: Not determined.
Crystal shape: Anhedral in porphyroclastic zone.
Preferred orientation: None.
Percent replacement: None.

**SECONDARY MINERALOGY:**

Total percent: <5%.
Texture: Amphibole replacing clinopyroxene generally less than 10% except in Pieces 2B and 2C where it is more than 20%.
Percent vein material: Trace.
Vein material: Amphibole vein appears in Piece 1B, 7 mm thick, inclining 40°.



**118-735B-78R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-6B**

**Olivine Gabbro**

**Pieces 1A-6B**

**COLOR:** Gray-dark gray.

**LAYERING:** Possible modal and size grading but somewhat obscured by deformation. Coarse grained interval between Pieces 5C and 6A. This interval is also rich in olivine.

**DEFORMATION:** Porphyroclastic in localized shear bands (Pieces 1A, 3A, 4B, 4C, 5A, 5B, and 6B). Clinopyroxene and plagioclase grains are stretched in these bands.

**PRIMARY MINERALOGY:**

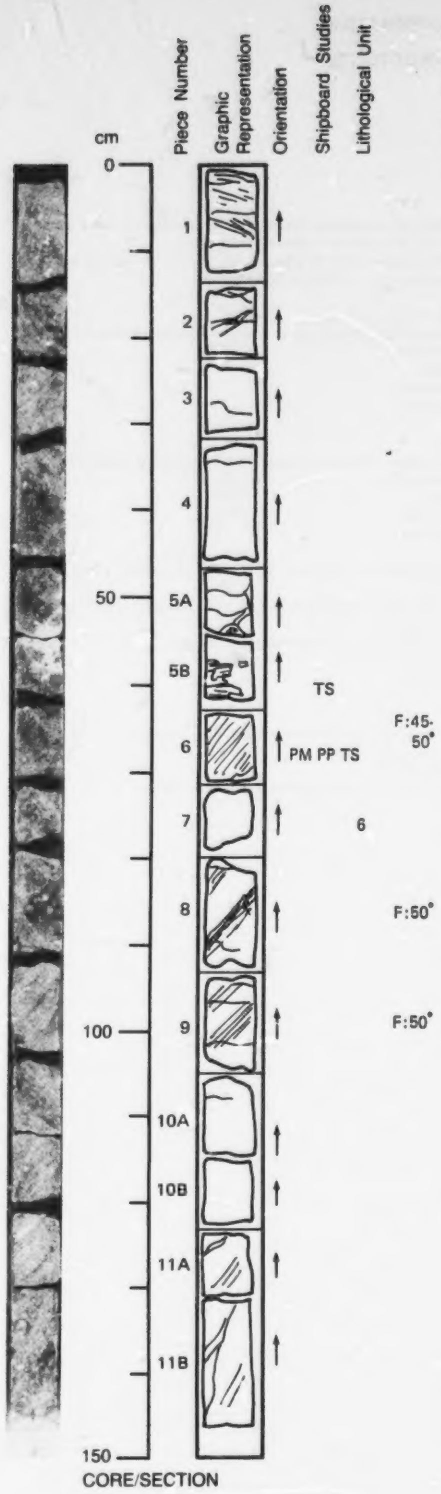
Plagioclase—Mode: 50%-60%.
Crystal size: 3-6 mm (in medium-grained intervals), up to 25 mm (in coarse-grained intervals), 0.5-20 mm (in porphyroclastic intervals).
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-5 mm (in medium-grained intervals), up to 40 mm (in coarse-grained intervals), 0.5-20 mm (in porphyroclastic intervals).
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10% (in medium-grained intervals), 15% (in coarse-grained intervals), 10% (in porphyroclastic intervals).
Crystal size: 2-5 mm (in medium-grained intervals), up to 25 mm (in coarse-grained intervals), 0.5-1 mm (in porphyroclastic intervals).
Crystal shape: Anhedral, poikilitically encloses plagioclase in places.
Preferred orientation: Not determined.
Percent replacement: Not determined

**SECONDARY MINERALOGY:**

Total percent: 20%.
Texture: Olivine largely replaced by mesh of magnetite + tremolite. Clinopyroxene replaced by amphibole.
Percent vein material: Not determined.
Vein material: Veins in Pieces 5C and 5D contain plagioclase and amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1
2
3
4
5A
5B
6
7
8
9
10A
10B
11A
11B
TS
PM PP TS
6
F:45-50°
F:50°
F:50°
CORE/SECTION

**118-735B-78R-4**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-11B**

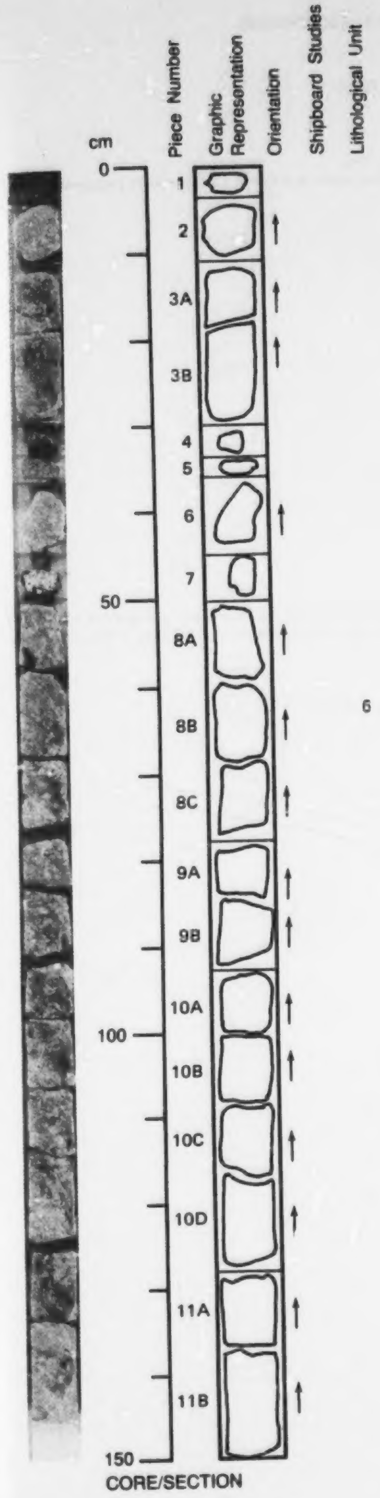
**Olivine Gabbro (Locally Foliated)**

**Pieces 1-11B**

**COLOR:** Gray.
**LAYERING:** Defined by size grading.
**DEFORMATION:** Mylonitic and porphyroclastic bands developed in Pieces 1, 6, 8, and 9. Other pieces might be weakly deformed.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: Up to 2 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 20%-30%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: < 15% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Slight alteration.
Texture: Amphibole replaces clinopyroxene (<15%), olivine shows small rims of tremolite(?). Few veinlets. One major vein in Pieces 5A and 5B: plagioclase and amphibole plus some other minerals. Few sulfides.
Percent vein material: Few veinlets. One major vein in Pieces 5A and 5B.
Vein material: Plagioclase and amphibole plus some other minerals.



**118-735B-79R-1**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-11B**

**Weathered Porphyroclastic Mylonite**

**Piece 1**

Identical to material in Core 118-735B-1D, and appears to be rubble from top of hole knocked down the hole during the re-entry preceding this core.

**Olivine Gabbro**

**Pieces 2-3B (top), 6-9A (top), and 9B (bottom) -11B**

**COLOR:** Gray.
**LAYERING:** Not determined.
**DEFORMATION:** Not determined.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 3-20 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: 3-20 mm.
Crystal shape: Intergranular to sub-ophitic.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode. 10%-15%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Oxides—Mode: <1%.
Crystal size: <1 mm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Sulfides—Mode: <1%.
Crystal size: <1 mm.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole rims and partially replaces pyroxene while olivine contains a mesh network of black iron-oxide veins.
Percent vein material: Not determined.
Vein material: Not determined.
**COMMENTS:** Medium grained intergranular to sub-ophitic olivine gabbro containing numerous disseminated sulfides.

**118-735B-79R-1 (continued)**

### Gneissic Mylonite

### Pieces 3B (bottom) -5, and 9A (bottom) - 9B (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Poorly foliated gneiss and mylonite.
**PRIMARY MINERALOGY:** Olivine gabbro described above is protolith. Clinopyroxene porphyroclasts locally replaced by amphibole.
**SECONDARY MINERALOGY:** Not determined.

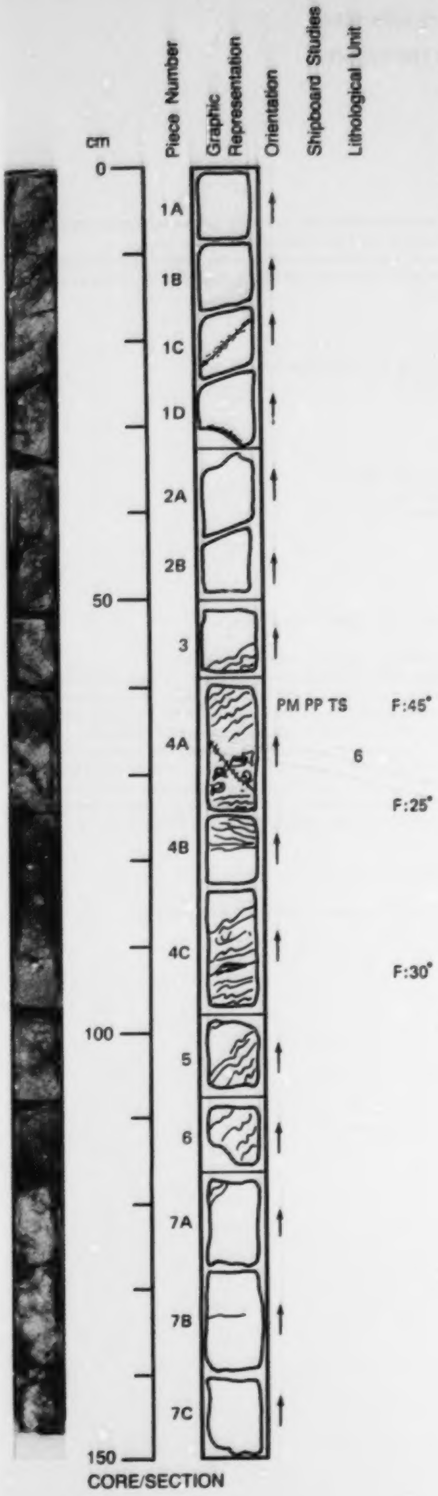
### Trondhjemite

### Piece 11A

**COLOR:** Grayish-white
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Not determined
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Quartz—Mode: Not determined.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**COMMENTS:** Aplitic sugary vein of intergrown plagioclase and quartz on back of Piece 11A associated with an ilmenite-sulfide enrichment vein seen running vertically on the face of this sample of altered gabbro.



## 118-735B-79R-2

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-7C**

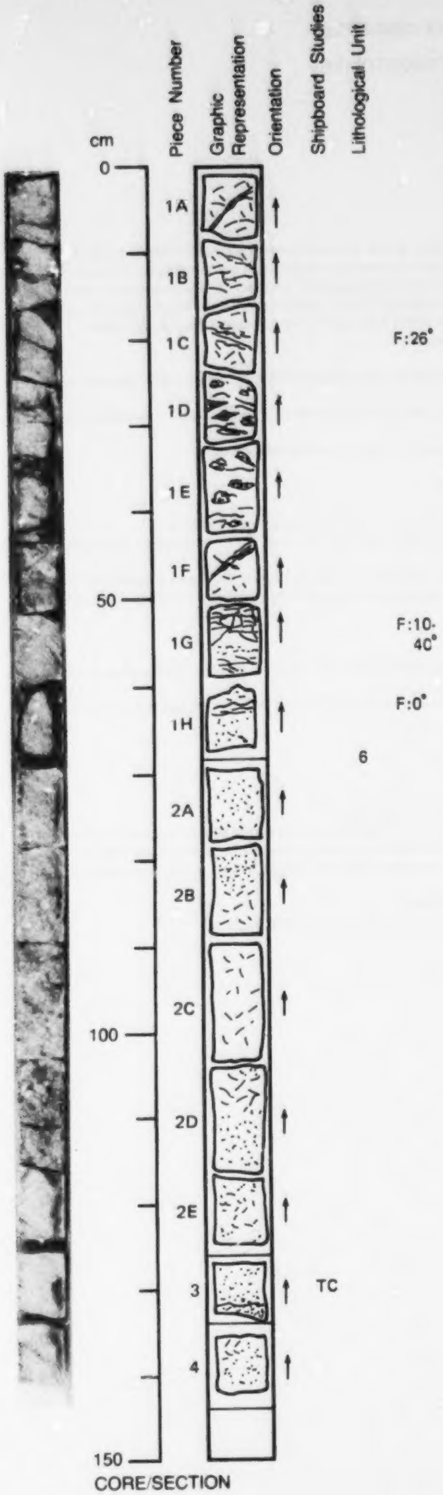
**Olivine Gabbro**

**Pieces 1A-7C**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Between 55-125 cm, gabbro is well foliated, porphyroclastic to nearly mylonitic. Foliation defined by elongate clinopyroxene and plagioclase porphyroclasts. In detail, between 56-66 cm the section is porphyroclastic metagabbro; between 66-74 cm, augen gneiss; between 74-80 cm, mylonite; between 80-82 cm, massive (underformed) gabbro; between 82-95 cm, porphyroclastic metagabbro; between 95-100 cm, mylonitic; and between 100-120 cm, porphyroclastic metagabbro.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55% (in coarse-grained interval, 0-55 cm), 58% (in very coarse-grained interval, 120-150 cm).
Crystal size: 5-12 mm (in coarse-grained interval, 0-55 cm), 10-20 mm (in very coarse-grained interval, 120-150 cm).
Crystal shape: Anhedral to subhedral in very coarse-grained interval.
Preferred orientation: None.
Percent replacement: Slight

Clinopyroxene—Mode: 40% in coarse- and very coarse-grained intervals.
Crystal size: 3-12 mm (in coarse-grained interval, 0-55 cm) 10-15 mm (in very coarse-grained interval, 120-150 cm).
Crystal shape: Anhedral in coarse-grained interval. Subhedral. Encloses plagioclase subophitically and completely encloses some small olivines in very coarse-grained interval.
Preferred orientation: None.
Percent replacement: Slight

Olivine—Mode: 5% (in coarse-grained interval, 0-55 cm), 2% (in very coarse-grained interval, 120-150 cm).
Crystal size: 3-4 mm (in coarse-grained interval, 0-55 cm), 5-15 mm (in very coarse-grained interval, 120-150 cm).
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: <5% total for undeformed areas.
Texture: Amphibole along vein in Piece 1C and in thin veins elsewhere. Traces of sulfides in upper part of section. Below 120 cm, olivine altered in mesh-like texture. Mesh defined by black, metallic-looking mineral, but olivine fresh in between mesh. A few thin, nearly horizontal white veins.
Percent vein material: Not determined.
Vein material: Amphibole plus an unidentified white material.



**118-735B-79R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-4

### Olivine Gabbro

### Pieces 1A-4

**COLOR:** Gray.

**LAYERING:** Layering defined by coarse and fine zones. One apparently graded layer from 110-70 cm. A very coarse layer with 3 cm pyroxenes and 2 cm plagioclase at 23-49 cm.

**DEFORMATION:** Porphyroclastic texture with interspersed mylonite in the upper 61 cm. Elongate porphyroclasts to 3 cm. Mylonite zones at 20, 54, and 60 cm; dips of mylonite highly variable from 10°-40° within single intervals.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 2-10 mm.
Crystal shape: Euhedral (small grains in clinopyroxene) to anhedral.
Preferred orientation: Not determined.
Percent replacement: Various.

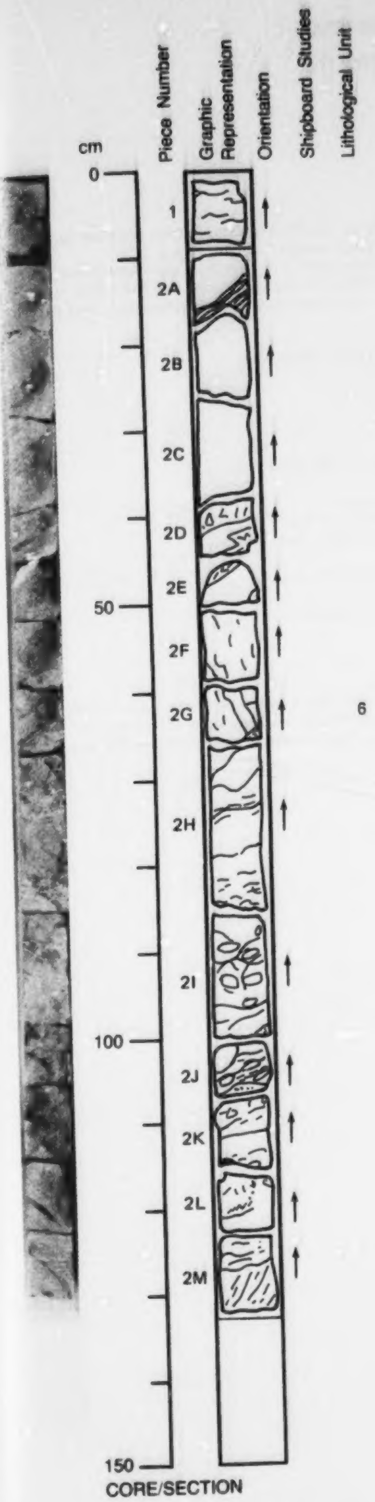
Clinopyroxene—Mode: 20%-40%.
Crystal size: 2-22 mm.
Crystal shape: Anhedral, ophitic to poikilitic.
Preferred orientation: Not determined.
Percent replacement: Various, altered to amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Various, altered to opaques and amphibole(?).

**SECONDARY MINERALOGY:**

Total percent: 30%-40% in deformed zone. Slight in lower part of core.
Texture: In upper, deformed section, extensive replacement of olivine by magnetite/amphibole, and clinopyroxene to fibrous green amphibole. A 2 mm thick amphibole vein crosscuts the foliation in Piece 1F. There are numerous subhorizontal fractures, some filled with feldspathic mineral. The finer shear zones are more extensively altered. There is a zone of fine, disseminated sulfides at the top of a mylonite band in Piece 3, as well as scattered sulfide throughout the top 60 cm. In the lower, undeformed part of the core, there is minor alteration of olivine and clinopyroxene. <2% subhorizontal (<1 mm wide) feldspathic veins throughout. One horizontal 1 mm wide amphibole vein in Piece 3. The pyroxenes here have a greenish cast on the cored surface which may reflect primary compositional differences rather than secondary alteration.
Percent vein material: 2%-5%.
Vein material: Amphibole and feldspathic mineral.

**COMMENTS:** Olivine may be as common as 30% in parts of the finer-grained sections.



## 118-735B-79R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-2M**

**Mylonitic Gabbro (Pieces 1 and 2H), Foliated Olivine Gabbro (Pieces 2A, 2G, 2H, and 2M), Olivine Gabbro (Pieces 2B-2F, and 2K-2M), and Porphyroclastic Gabbro (Pieces 2A and 2H-2J).**

**COLOR:** Greenish gray.

**LAYERING:** There are grain size contacts in Pieces 2A, 2B, 2D, 2K, 2L, and 2M. The coarse-grained gabbro has grains up to 2 cm long, the fine-grained gabbro has average grain size of 1-2 mm.

**DEFORMATION:** Irregular to folded deformation planes. The foliation is defined in porphyoclastic types and is well developed in fine-grained gabbros. The foliation is defined by stretching and elongation of plagioclase and pyroxene. The grain size can change from 2.5 cm to a few millimeters.

**PRIMARY MINERALOGY:**

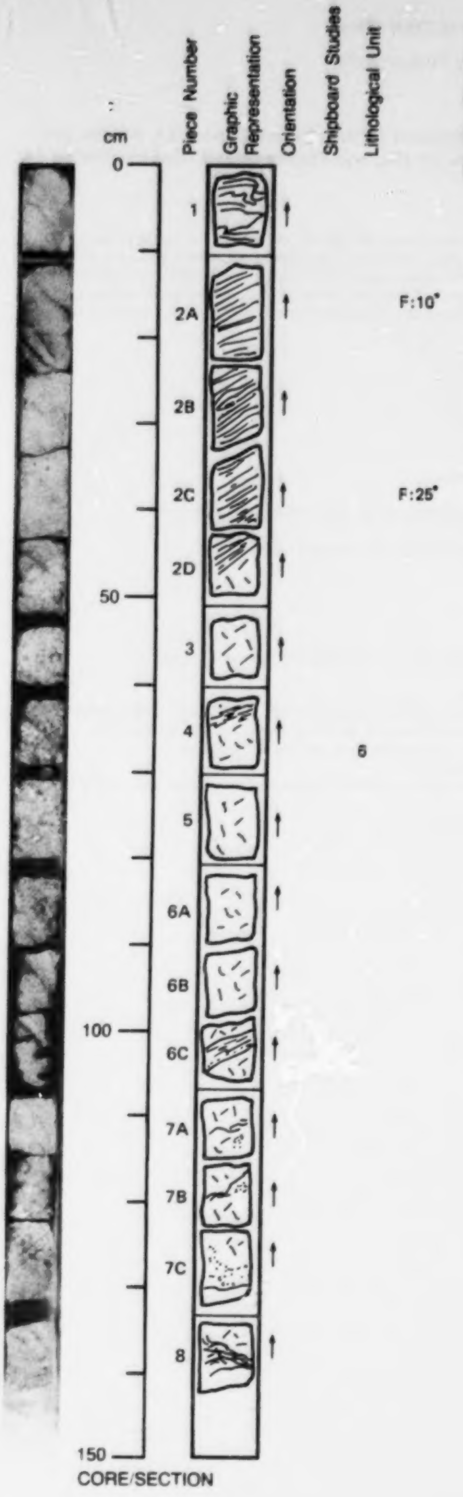
Plagioclase—Mode: 40%-50%.
Crystal size: 10-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Variable.
Percent replacement: Slight.

Clinopyroxene—Mode: 50%-60%.
Crystal size: 2-25 mm.
Crystal shape: Oikocrystic, containing plagioclase idiomorphic inclusions.
Preferred orientation: Variable.
Percent replacement: Slightly to moderately replaced by amphibole.

Olivine—Mode: 1%-5%.
Crystal size: 0.5-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderately replaced by magnetite, talc, and chlorite(?).

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Coronitic. Olivine is replaced by magnetite + talc + chlorite(?). Clinopyroxene is replaced by green amphibole particularly in deformed zones. Sulfides are rare and disseminated in intergranular spaces (see Piece 2K) and are fractured.
Percent vein material: Not determined.
Vein material: Veins are filled with a mixture of plagioclase, carbonates, and epidote (green color).
Cracks are filled with amphiboles.



**118-735B-79R-5**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-8**

**Olivine Gabbro**

**Pieces 1-8**

**COLOR:** Gray.

**LAYERING:** None. A near troctolitic layer at 63-98 cm with 2%-8% clinopyroxene. There are some fine grained pods in the otherwise coarse-grained section.

**DEFORMATION:** The upper part (0-45 cm) is mylonitic with 1-4 mm pyroxene and olivine porphyroclasts. Foliation dips 10°-25° except in Piece 1 where it is subhorizontal in part and folded. Mylonitic bands occur at 64, 104, 120, 132, and 137 cm. They often seem associated with finer grained parts of the core.

**PRIMARY MINERALOGY:**

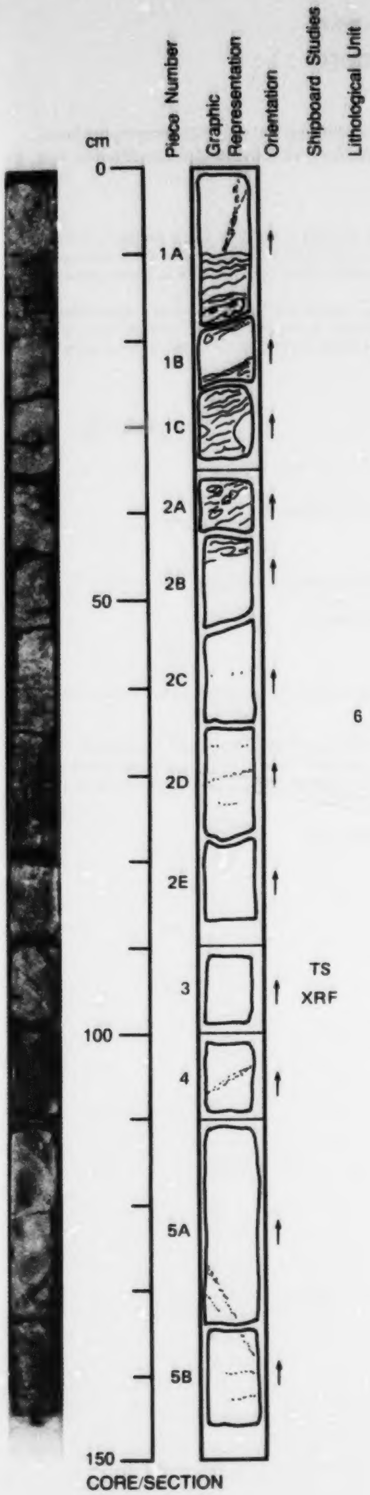
Plagioclase—Mode: 40%-55% (70%-80% in troctolitic layer).
Crystal size: 2-6 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-35% (2%-8% in troctolitic zone).
Crystal size: 4-40 mm.
Crystal shape: Anhcdral, oikocrystic in places.
Preferred orientation: Clasts define foliation at 0-60 cm.
Percent replacement: Extensively amphibolized in mylonitic zone.

Olivine—Mode: 15%-20% (20%-40% in troctolitic zone).
Crystal size: 3-8 mm.
Crystal shape: Anhedral, intergrown with plagioclase.
Preferred orientation: Not determined.
Percent replacement: 30%-50%.

**SECONDARY MINERALOGY:**

Total percent: 30%-40% in deformed zone.
Texture: Clinopyroxene is extensively amphibolitized in deformed zones; there are often secondary opaques associated with the mylonitic zones, particularly at boundary near 45 cm. Much of the clinopyroxene has a dull emerald-green color in many places on the cored surface.
Percent vein material: Not determined.
Vein material: Not determined.



**118-735B-79R-6**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-5B

### Olivine Gabbro

### Pieces 1A-2B (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** From 0-10 cm, no deformation. From 10-45 cm, rocks are highly deformed plastically, and range from porphyroclastic metagabbro to mylonitic. Foliation defined by stretched pyroxenes and plagioclase. This interval has approximately 15%-20% iron-oxides in thin layers.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 42%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral. Clinopyroxene is brownish in color.
Preferred orientation: None.
Percent replacement: Slight.

Olivine—Mode: 2%-3%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: Slight.
Texture: Thin vein has amphibole, plagioclase and epidote(?). Traces of sulfides.
Percent vein material: Not determined.
Vein material: Plagioclase, amphibole, and epidote(?).
**COMMENTS:** Primary mineralogy from 0-10 cm interval.

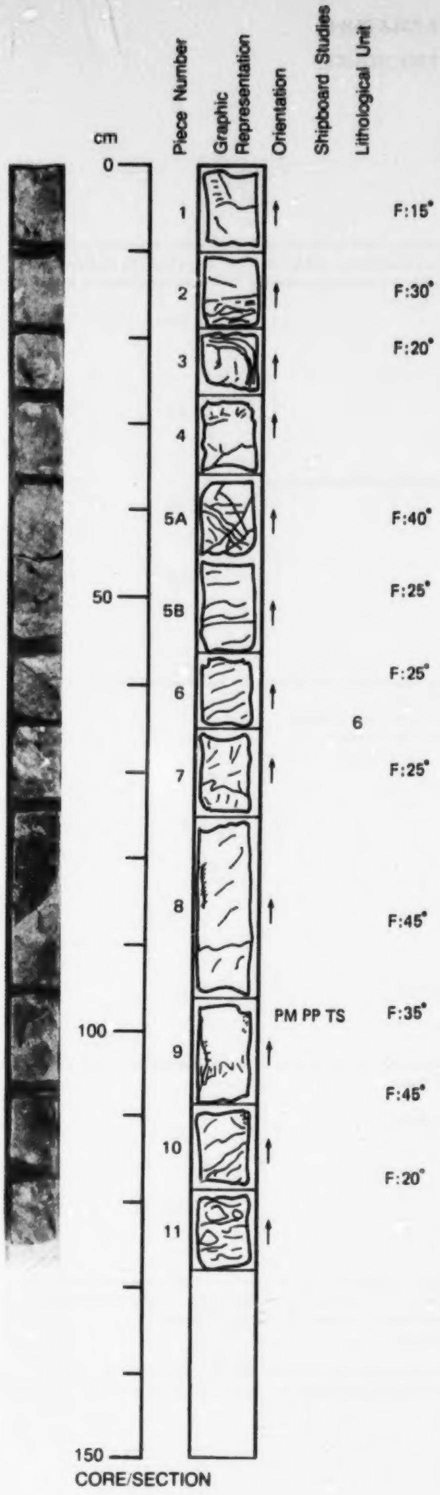
### Olivine-Rich Gabbro

### Pieces 2B (bottom) -5B

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-50%.
Crystal size: 10-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 15%-20%.
Crystal size: 10-20 mm.
Crystal shape: Subhedral. Clinopyroxene is a dark green color as opposed to brown like other clinopyroxene in all other earlier cores.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 30%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <1%.
Texture: Alteration of this interval is extrememly low and shows no apparent connection with veins, even thin ones. Surrounding the clinopyroxene and olivine, and filling interstitial areas, is a small, translucent, pale pinkish-brown mineral, probably amphibole.
Percent vein material: Not determined.
Vein material: None.
**COMMENTS:** Primary mineralogy from 45-100 cm interval. The interval from 100-150 cm is similar mineralogically and modally to that between 45-100 cm, but texture is equigranular and is a diabase in grain size (<0.5 mm).



**118-735B-79R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-11**

**Foliated Gabbro, (Pieces 1-4), Mylonitic Gabbro (Pieces 5A and 5B), Prophyroclastic Olivine-Rich Gabbro (Pieces 6 and 11), and Undeformed Olivine Gabbro (Pieces 7, 8, 9 and 10).**

**COLOR:** Greenish gray.

**LAYERING:** There are grain-size and compositional contacts in Pieces 1, 2, 3, 4, 5A, 5B, 7, 9, and 10. The foliation and sealed fault planes may cause part of these contacts. Grain size variation ranges from 1-2 cm to 1-2 mm. The composition varies from troctolite to olivine gabbro to light brown olivine-bearing gabbro.

**DEFORMATION:** Varies from intense (see list of rock names) with mylonitic zones to porphyroclastic gabbros and undeformed gabbros. Deformation is very irregular and foliation dips can vary from one piece to another. This is high-temperature deformation under relatively anhydrous conditions (see previous sections).

**PRIMARY MINERALOGY:**

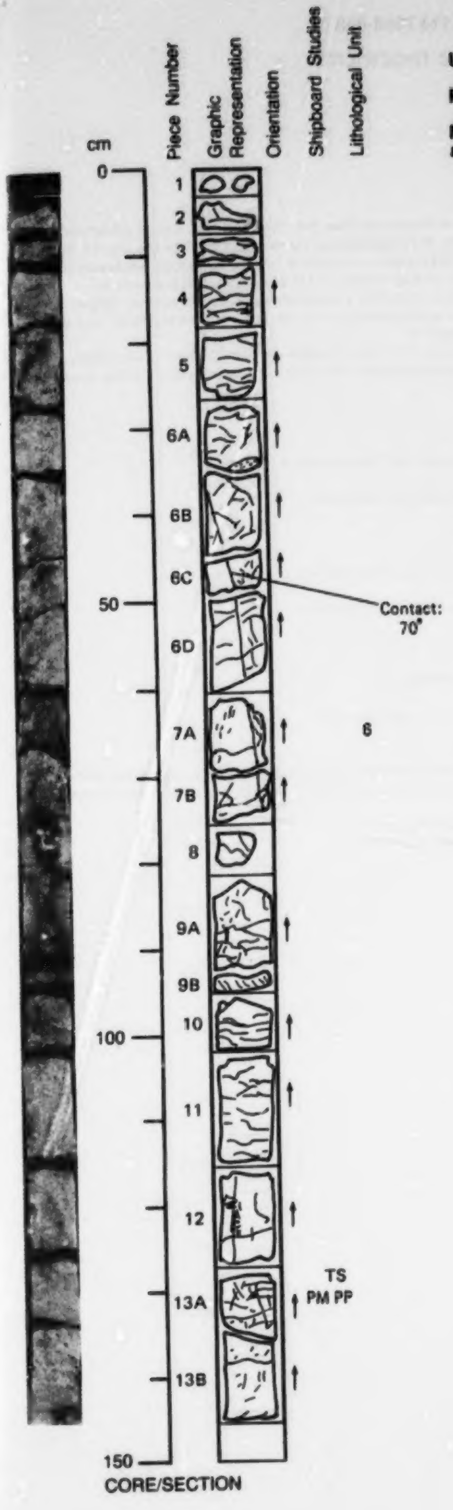
Plagioclase—Mode: 60% (in troctolite).
Crystal size: 1-20 mm.
Crystal shape: Elongated.
Preferred orientation: Variable.
Percent replacement: Slight.

Clinopyroxene—Mode: 5% (in troctolite), 40% (in gabbro).
Crystal size: 1-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Variable.
Percent replacement: Slight to moderate replacement by amphibole.

Olivine—Mode: 40% (in troctolite), 10% (in gabbro).
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not visible.
Percent replacement: Slight to moderate replacement by talc, magnetite, and chlorite(?).

**SECONDARY MINERALOGY:**

Total percent: <1% in undeformed gabbro.
Texture: Coronitic. Olivine is replaced by a mixture of talc + magnetite + chlorite(?). Clinopyroxene is partly replaced by dark green amphibole(?). Sulfides and iron oxides are observed in Pieces 3-11 and lesser amounts in Pieces 1 and 2. Veins (6 mm thick) are filled with plagioclase, carbonate, and acicular actinolite.
Percent vein material: Not determined.
Vein material: Plagiolase, carbonate, and actinolite.



## 118-735B-80R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Piece 1-13B

### Massive Gabbro (Pieces 5-7B, and 13B), Foliated Olivine Gabbro (Pieces 1-4, 9A, 9B, and 13A), and Porphyroclastic Gabbro (Pieces 10-12)

**COLOR:** Grass green to pinkish gray.

**LAYERING:** There is a succession from coarse-grained gabbro in Pieces 5 to 6B and to fine-grained gabbro in Pieces 6C, 6D, and 7A. In Piece 7B a fine-grained gabbro is transformed into a mylonite before returning to coarse-grained gabbro in Pieces 10 and 11. The grain size is respectively 1 cm, 2-5 mm, and 1 mm. The contact between coarse-grained gabbro and the fine-grained gabbro is 70° dipping. There is an increase of plagioclase content as the grain size decreases. The very fine-grained gabbro is a highly deformed rock or alternatively a real primary fine-grained olivine- and plagioclase-rich gabbro. There is another contact in Piece 13B.

**DEFORMATION:** The section is heterogeneously deformed. (See rock names for piece numbers). The deformation goes from mylonitic (with augen) to porphyroclastic to undisturbed gabbro. The foliation is parallel to the layering and can have transposed the original layering but the mineral foliation in the gabbro is oblique to the mylonitic zone (1-3 cm thick). The foliation in the porphyroclastic gabbro is defined by stretching of pyroxene and plagioclase.

**PRIMARY MINERALOGY:**

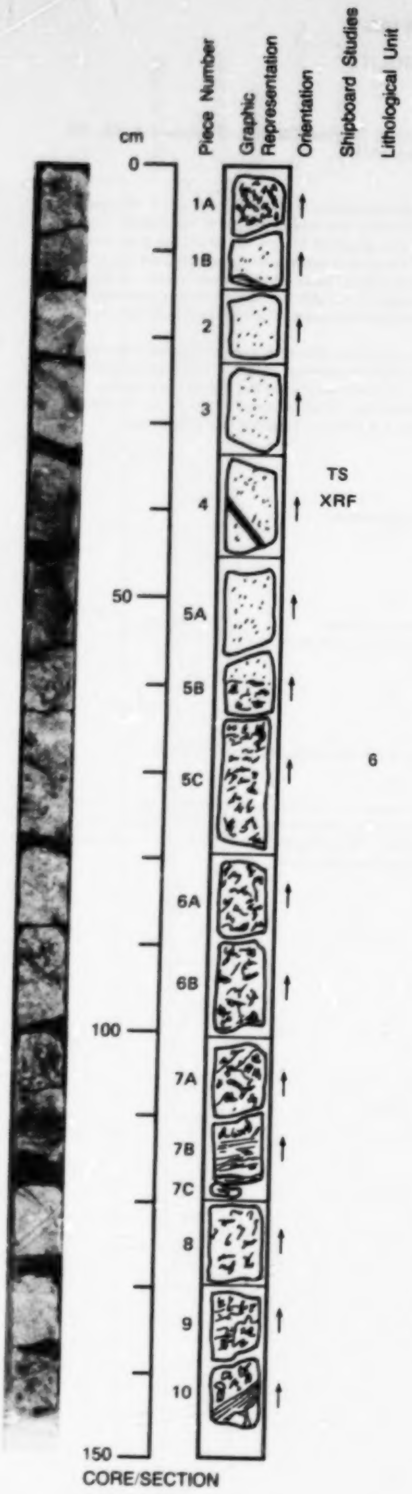
Plagioclase—Mode: 55%-70%.
Crystal size: Up to 5 mm.
Crystal shape: Euhedral.
Preferred orientation: Visible in deformed samples.
Percent replacement: None.

Clinopyroxene—Mode: 10%-25%.
Crystal size: Up to 1 cm.
Crystal shape: Oikocrysts.
Preferred orientation: Visible in deformed samples.
Percent replacement: Slight replacement by amphibole(?).

Olivine—Mode: 10%-20%.
Crystal size: Up to 5 mm.
Crystal shape: Euhedral to rounded.
Preferred orientation: Not visible.
Percent replacement: Slight replacement by magnetite, talc, and chlorite(?).

**SECONDARY MINERALOGY:**

Total percent: <1%.
Texture: Coronitic. Olivine is replaced locally by a mixture of magnetite + talc + chlorite(?). Clinopyroxene (brown when fresh) is altered to grass green amphibole(?). There is an outer rim of dark amphibole. Sulfides are abundant (1%) in Pieces 6B, 6C, 6D, and 7A and less than 1% elsewhere. They are chalcopyrite, pentlandite, and pyrite.
Percent vein material: None.
Vein material: None.



118-735B-80R-2

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-10**

**Olivine Gabbro**

**Pieces 1A-10**

**COLOR:** Gray.

**LAYERING:** Banded orthocumulates and mesocumulates. 0-11 cm: Troctolitic olivine gabbro (30% olivine, 5%-10% clinopyroxene, 65% plagioclase) mesocumulate. 11-59 cm: Ophitic olivine gabbro (medium-grained), olivine crystals enclosed in 1-2 cm plagioclase oikocrysts (19% olivine, 62% plagioclase, 15% clinopyroxene). 60-145 cm: Subophitic plagioclase orthocumulate (65% plagioclase, 20%-25% clinopyroxene, 10%-15% olivine). Sequence grades downward from 1 cm plagioclase laths at 73 cm to 2 cm laths at 110 cm and then remains coarse to bottom of section.

**DEFORMATION:** Mylonitic zones are dense and black. Contain great enrichment of iron-titanium oxides at 115 cm (3 cm thick mylonite zone) and at 145 cm (0.8 cm thick mylonite zone). Zones are also enriched in sulfides.

**PRIMARY MINERALOGY:**

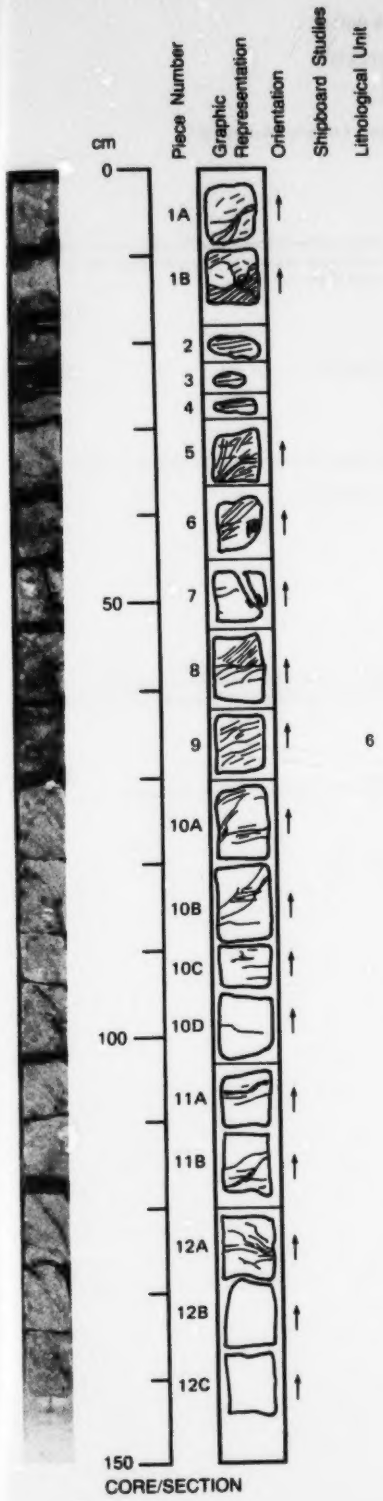
Plagioclase—Mode: 62%-65%.
Crystal size: 1-20 mm.
Crystal shape: Anhedral oikocrysts and intergranular.
Preferred orientation: None.
Percent replacement: Slight except near mylonites.

Clinopyroxene—Mode: 5%-25%.
Crystal size: 0.2 mm.
Crystal shape: Anhedral intergranular to subophitic.
Preferred orientation: None.
Percent replacement: Slight except near mylonites.

Olivine—Mode: 10%-30%.
Crystal size: 0.3-1 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: Slight except near mylonites.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Difficult to assess in hand specimen, but olivine meshed by iron oxides. Piece 4 cut by felsic vein 1.5 mm across. A separate generation is represented by an oxide-sulfide-rich 2 mm thick vein in Piece 4.
Percent vein material: Not determined.
Vein material: Plagioclase, oxides, and sulfides.



**118-735B-80R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-12C**

**Olivine Gabbro**

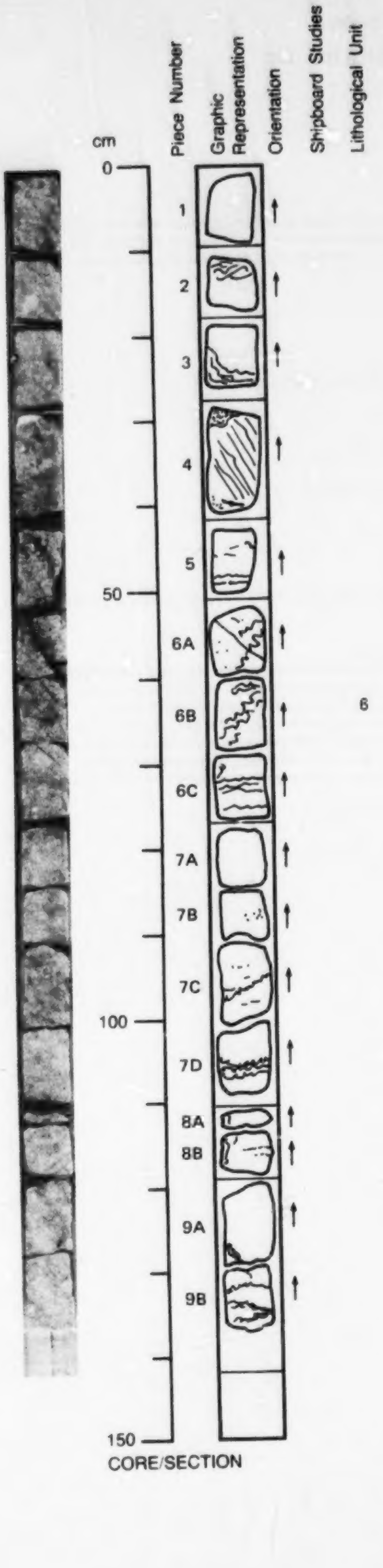
**Pieces 1A-12C**

**COLOR:** Gray.
**LAYERING:** None apparent. May be some olivine-rich zones. It is difficult to tell with deformation.
**DEFORMATION:** Porphyroclastic to mylonitic bands throughout: 8, 10, 15-43, 58, 63-72, 85, 108, 114, and 125 cm, often irregular dip, wavy contacts. Often foliation climbs and bends (Pieces 1A and 1B), porphyroclasts 3-14 mm in size.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 1-11 mm.
Crystal shape: Euhedral, anhedral.
Preferred orientation: Not determined.
Percent replacement: Various, freshest Pieces are 12B and 12C.

Clinopyroxene—Mode: 20%-30%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral, commonly oikocrysts.
Preferred orientation: Not determined.
Percent replacement: Various by amphibolitized.

Olivine—Mode: 10%-20%.
Crystal size: 1-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Meshwork alteration, two large (15 mm) pseudomorphs at 42 and 50 cm.

**SECONDARY MINERALOGY:**
Total percent: 30%-50% in deformed zones.
Texture: Olivine commonly replaced by magnetite/talc/ tremolite mesh particulary in deformed zones. In mylonite zones a lot of clay in olivine pseudomorphs, at least in large ones. Mylonitized zone has a greenish-gray cast indicating extensive amphibolitization of clinopyroxene (30-40%). There is a zone of opaques in a mylonitic zone at 55-65 cm (up to 30% of an aggregate of fine (<1 mm) opaques with disseiminated sulfide). Note: Clinopyroxenes have a very brownish cast. They appear replaced or rimmed by a dull-emerald green clinopyroxene (amphibole?) in places. Similar emerald-green pyroxene have been described in other sections.
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-80R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-9B

### Olivine Gabbro to Porphyroclastic Metagabbro, Locally Mylonitic

### Pieces 1-3, and 5-6A (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Deformed layers are complexly intermixed with totally undeformed sections over a scale of centimeters. Foliation varies in orientation dramatically as well—from nearly vertical to horizontal, even within a single piece (See Piece 3).
**PRIMARY MINERALOGY:**
Plagioclase— Mode: 45%.
Crystal size: 10-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Not determined.

Clinopyroxene—Mode: 45%.
Crystal size: 5-20 mm.
Crystal shape: Anhedral. Clinopyroxene is green in color with brownish rims; it subophitically to ophitically encloses plagioclase.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: 4-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Contains some layers stained by iron-oxides. Actinolite on grain boundaries. Oxides appear to be associated with amphibole. Trace of sulfides. Olivine altered in mesh-like fashion by black metallic mineral.
Percent vein material: None.
Vein material: None.

**COMMENTS:** Olivine has a yellowish color (iron-rich) while clinopyroxene is pale brown.

## 118-735B-80R-4 (continued)

### Diabase

### Piece 4

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 53%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 23%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Olivine—Mode: 22%.
Crystal size: <0.5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: 2%.
Texture: Very fresh. Only cross-cut by a few thin, nearly horizontal white veins. Large vein in upper corner of Piece 4 composed of plagioclase and trace of actinolite.
Percent vein material: 1%-2%.
Vein material: Sodic plagioclase and actinolite.

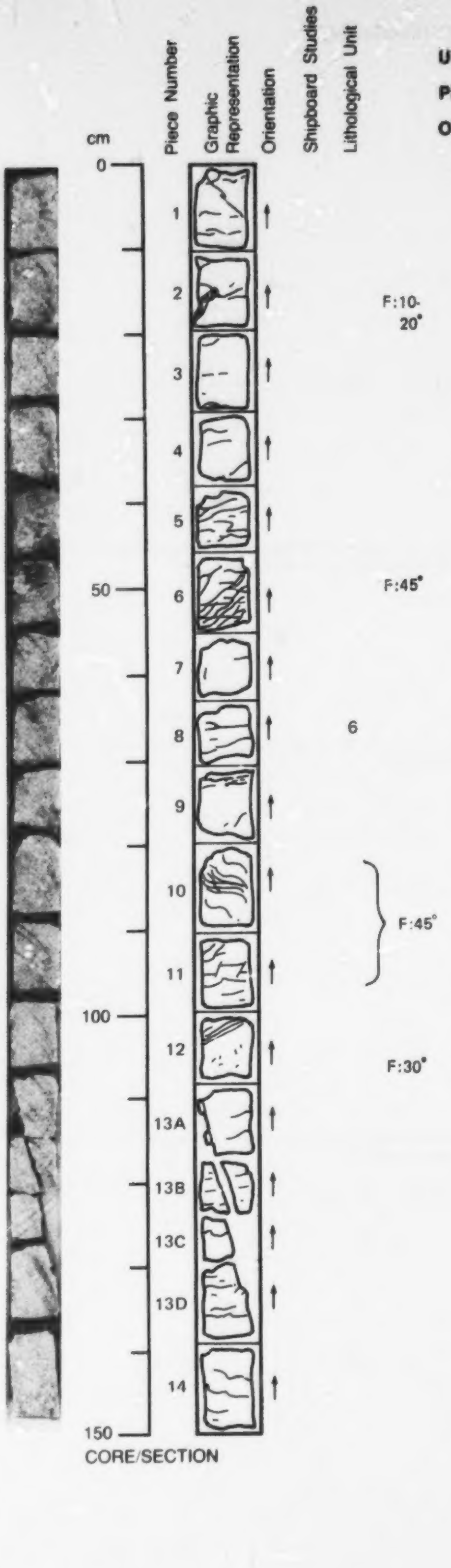
### Olivine Gabbro

### Pieces 6A (bottom) -9B

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Most strongly deformed intervals (Pieces 7D, 9A, and B) throughout section contain secondary iron-oxides in layers parallel to foliation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 5-20 mm.
Crystal shape: Andedral to enhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 35%.
Crystal size: 8-15 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: Slight.

Olivine—Mode: 5%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Numerous thin nearly horizontal white veins. Thin amphibole vein in Piece 7C. Olivine altered in mesh-like fashion by black, metallic mineral.
Percent vein material: 2%-3%.
Vein material: Sodic plagioclase and amphibole.



### 118-735B-80R-5

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-14

### Olivine-Rich Gabbro, Some Foliated to Mylonitic Gabbro

**COLOR:** Pink-brownish gray.

**LAYERING:** There is a contact between coarse-grained gabbro and fine-grained gabbro in Piece 5. This may be due to intense deformation of fine grained part (<1 mm in diameter versus 3-10 mm).

**DEFORMATION:** Foliation is visible in Pieces 1, 2, 6, 10. Piece 6 is a porphyroclastic gabbro. Piece 10 is a mylonitic gabbro. The pyroxene and plagioclase are deformed and recrystallized into neoblasts (grain size reduction from 5-10 mm to <3 mm).

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral and enclosed in larger clinopyroxene oikocrysts (subophitic texture).
Preferred orientation: Variable.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-20 mm.
Crystal shape: Oikocrystic with chadacrysts of plagioclase.
Preferred orientation: Variable.
Percent replacement: 30% by amphibole.

Olivine—Mode: 5%-20%.
Crystal size: 1-4 mm.
Crystal shape: Rounded.
Preferred orientation: Not determined.
Percent replacement: 20%-30% replaced by talc and magnetite.

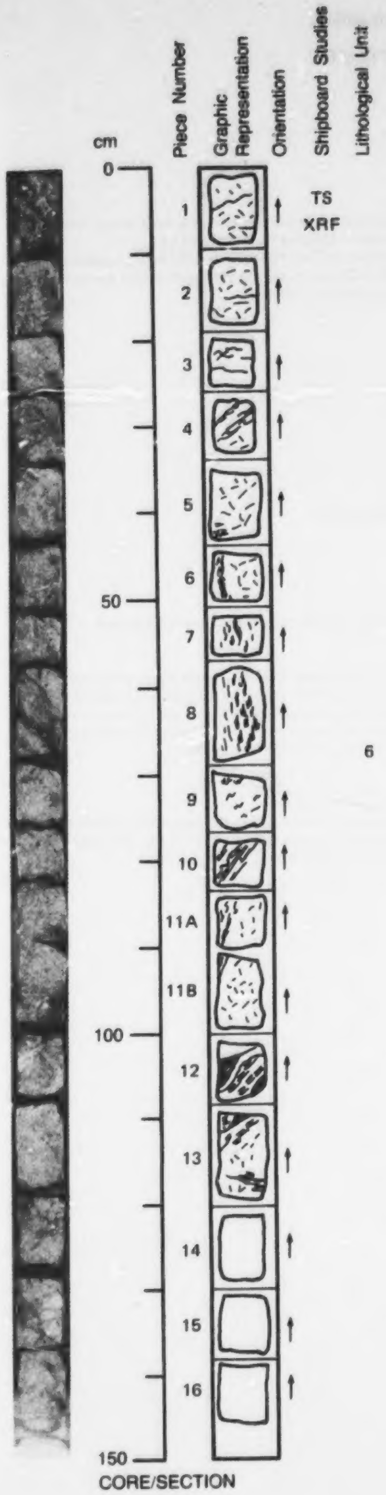
**SECONDARY MINERALOGY:**

Total percent: 20%.

Texture: Coronitic. Plagioclase is in part albitized (Pieces 1 and 11). Olivine is partly (20-30%) replaced by talc and magnetite. Clinopyroxene is partly (30%) replaced by amphibole only in deformation zones. There is an oxide-rich zone associated with disseminated sulfides in Piece 10. Sulfides are disseminated throughout the section.

Percent vein material: Not determined.

Vein material: Pieces 13A to 13D: Talc-rich vein (2 mm thick) cutting the rock at 70°. Piece 2: Contains a vug partially filled with plagioclase (sodic plagioclase), actinolite, and quartz. Late-subhorizontal cracks are filled with amphibole.



## 118-735B-80R-6

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-16

### Olivine Gabbro

### Pieces 1-16

**COLOR:** Gray to gray-green.

**LAYERING:** Some coarse to fine grain size variation. There is a coarse-grained olivine-rich layer at 126-133 cm. Some of this is original layering but is largely obscured by deformation. There is an oxide-rich layer at 115-140 cm.

**DEFORMATION:** A number of mylonitic-porphyroclastic bands—many steeply dipping—are present in Pieces 5-8 and 10 and 11. Small plagioclase-actinolite segregations on outside of shear band at 108 cm. Gabbro is least deformed in Pieces 1, 2 and 11B.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: 3-8 mm, rarely to 10 mm.
Crystal shape: Euhedral, subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

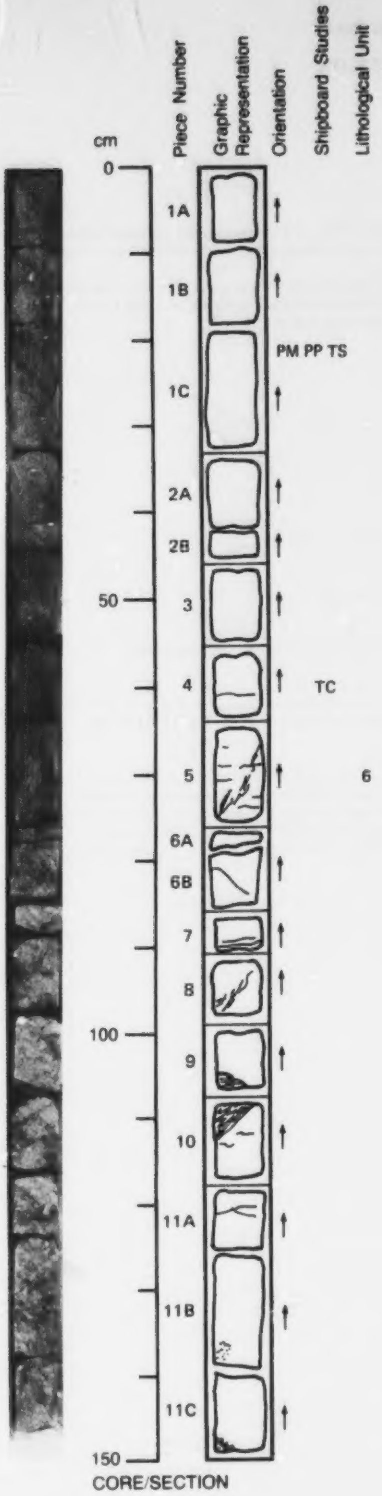
Clinopyroxene—Mode: 30%-40%.
Crystal size: 3-7 mm.
Crystal shape: Subophitic to granular.
Preferred orientation: Not determined.
Percent replacement: Extensive along shears to actinolite.

Olivine—Mode: 10%-15%.
Crystal size: 2-4 mm, rarely to 14 mm (at 132 cm).
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Common replacement to talc, tremolite, and magnetite.

**SECONDARY MINERALOGY:**

Total percent: Various, most extensive along shear zones.
Texture: Usual olivine alteration (talc/tremolite/magnetite). Extensive actinolite developed along shear zones after clinopyroxene particularly well-developed on shear in Pieces 6-8.
Percent vein material: Not determined.
Vein material: Not determined.

**COMMENTS:** Trace sulfides (<1 mm) throughout. Olivine- and oxide-rich zone at 120-140 cm is very coarse-grained—it appears to have been somewhat deformed, judging from the plagioclase shapes—the plagioclase has a very greenish cast from fine-grained amphibole in veins. There is up to 30% oxide in this zone; most likely of secondary origin, though olivine here is still rather fresh. Rock may have been a troctolite. The clinopyroxene, particularly in Pieces 1 and 2, has a very pink-brown color.



**118-735B-80R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-11C**

**Olivine Gabbro**

**Pieces 1A-11C**

**COLOR:** Gray, gray-green.

**LAYERING:** None. At least 2 coarse to fine bands dipping out of the core at a steep angle (about 60°). There is an oxide-rich zone at 80-97 cm and a feldspathic clot at 138 cm.

**DEFORMATION:** Upper 75 cm of core are mylonitized gabbro. Foliation defined by elongation of pyroxene, does not appear well-developed enough to account for grain size reduction—also no porphyroclasts. A fine-grained gabbroic protolith is inferred.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%.
Crystal size: 2-10 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 3-13 mm.
Crystal shape: Subhedral to oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Variously by amphibolitized.

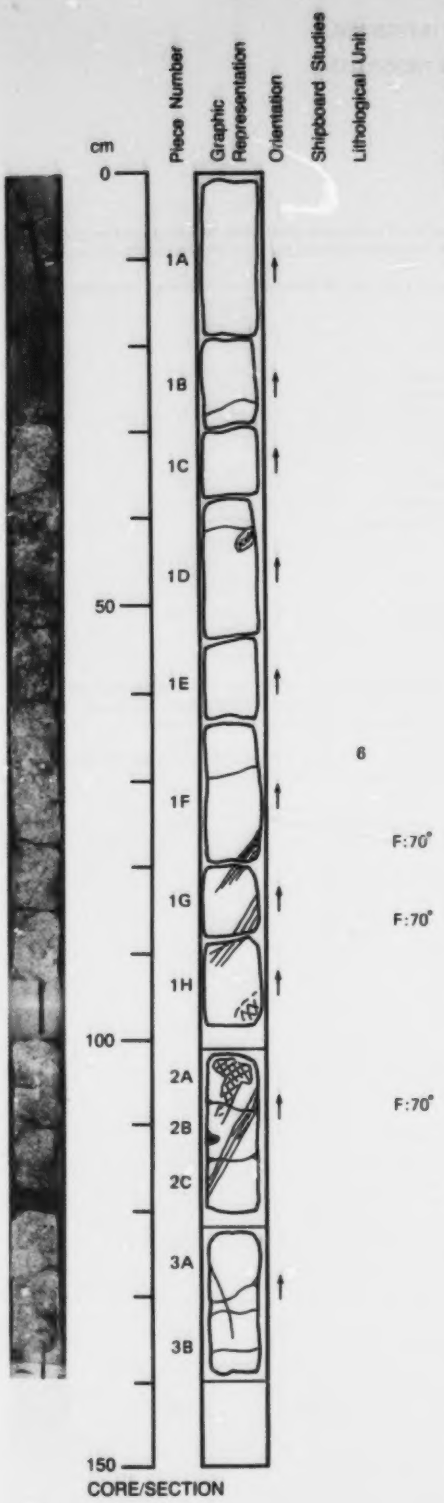
Olivine—Mode: 10%.
Crystal size: 3-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Commonly altered to mesh of talc, tremolite, and magnetite.

**SECONDARY MINERALOGY:**

Total percent: Extensive in shear zones.
Texture: Extensive amphibolitization of clinopyroxene in shear zones. Large amphibole veins in Pieces 5 and 8. Olivine is commonly altered in whole or part to magnetite/talc/tremolite mesh. There are abundant oxides (probably secondary) associated with the shear zones. They are concentrated along the bottom of a mylonitic zone in Piece 10. The oxide development in these sections is associated with deformation and amphibolitization.
Percent vein material: Not determined.
Vein material: Amphibole.

**COMMENTS:** Grain sizes are less than 1 mm in mylonitic zones.

Modes of deformed rock are hard to determine. In addition to the plagioclase, altered olivine and clinopyroxene, there is about 20% oxides throughout the upper 75 cm. As noted this deformed zone may have had a microgabbro, rather than gabbro, protolith.



### 118-735B-81R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-3B

### Olivine and Iron-Titanium Oxide-Rich Metagabbro (Pieces 1A and 1B), Medium-Grained Olivine Gabbro (Pieces 1B-1D, and 1G-3B), Coarse-Grained Olivine Gabbro (Pieces 1F and 1G), and Plagioclase- and Olivine-Rich Coarse-Grained Gabbro (Pieces 1D-1F)

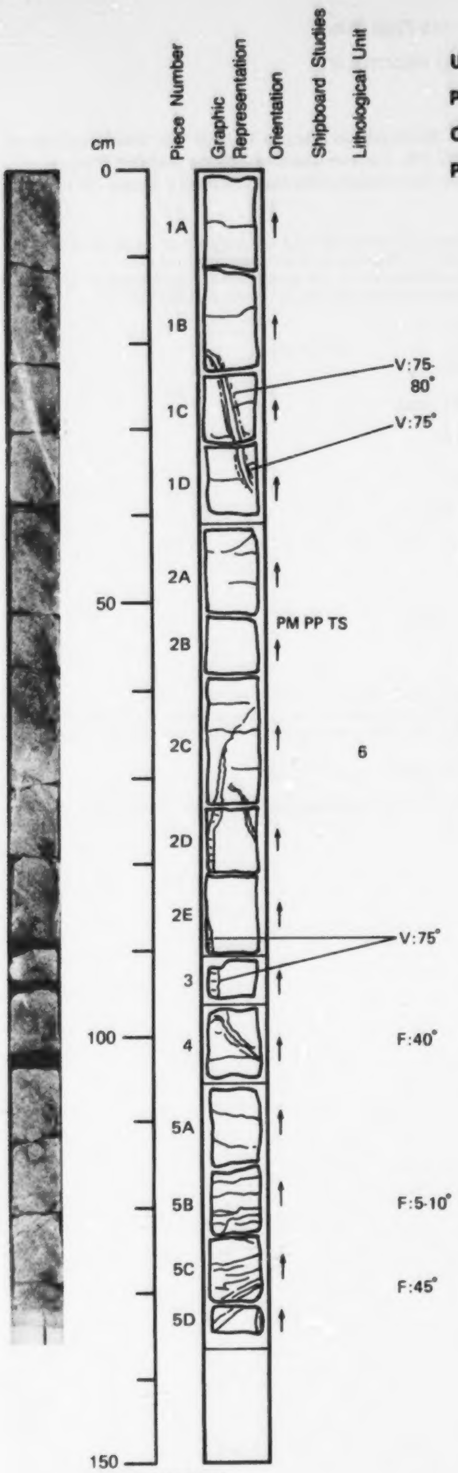
**COLOR:** Gray.
**LAYERING:** Modal (see above). Also grain size variations: <0.4 cm (0-28 cm); <1 cm (28-40 cm); <2 cm (40-70 cm); <1.5 cm (70-83 cm); <1 cm (below 83 cm). No magmatic foliation.
**DEFORMATION:** Discrete shear zones in Pieces 1F, 1G, 1H, 2A, 2B, and 2C. These shear zones have a porphyroclastic to augen gneissic foliation and are rich in iron-titanium oxides.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-70%.
Crystal size: See layering.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 5%-35%.
Crystal size: See layering.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 5%-25%.
Crystal size: See layering.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Ilmenite—Mode: 0%-15%.
**SECONDARY MINERALOGY:**
Total percent: Moderate to extensive in Pieces 1H, 2A, and 2B.
Texture: Two types of transformations: albitization along veins in Pieces 1D, 1H, 2A, and 2B; amphibolitization in all pieces, often more extensive in the iron-titanium oxide-rich intervals.
Percent vein material: <1%.
Vein material: amphibole in thin veins.

**COMMENTS:** The pyroxene is very brown-it could be orthopyroxene or altered clinopyroxene.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
2A
2B
2C
2D
2E
3
4
5A
5B
5C
5D
V:75-80°
V:75°
PM PP TS
6
V:75°
F:40°
F:5-10°
F:45°
CORE/SECTION

**118-735B-81R-2**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-5D

### Olivine Gabbro

### Pieces 1A-5D

**COLOR:** Medium gray.

**LAYERING:** Weak layering, essentially defined by grain size gradations. Average grain size groups: fine-grained (0.2-0.5 cm), medium- to fine-grained (0.3-0.8 cm), medium-grained (0.5-1.0 cm), and coarse-grained (1.5-2.0 cm).

**DEFORMATION:** Mylonitic bands on Pieces 4, 5A, and 5B (inclination as indicated), otherwise undeformed.

**PRIMARY MINERALOGY:**

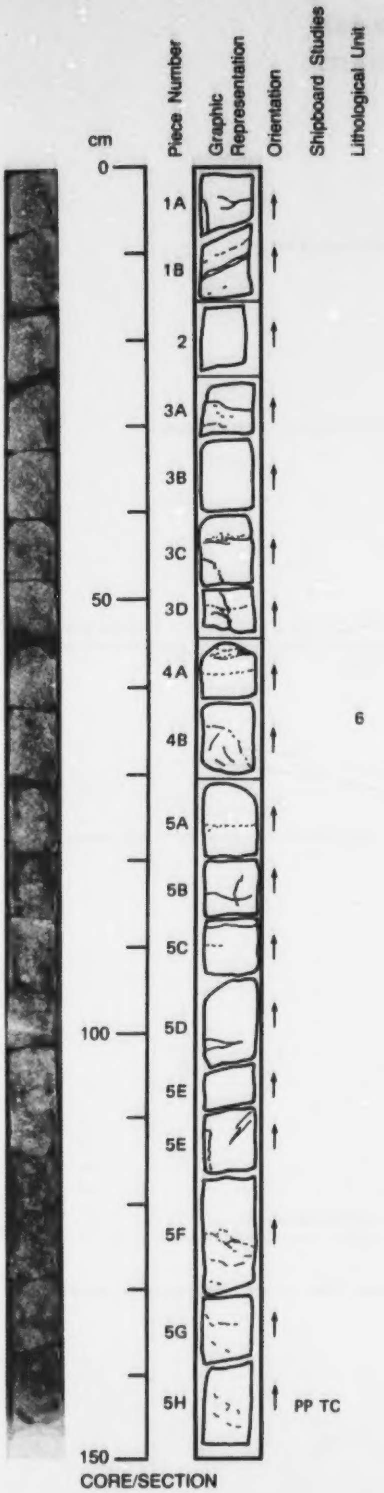
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

Olivine—Mode: 5%-15%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight alteration.
Texture: Amphibole replacement of clinopyroxene (<10%). One or two major veins (as indicated) in Pieces 1B, 1C, 2A, 2B, 2C, 2D, 3, and 4 (may be one vein) consisting of plagioclase plus green amphibole. Secondary sulfides abundant in Piece 5.
Percent vein material: Not determined.
Vein Material: One or two major veins (as indicated) in Pieces 1B, 1C, 2A, 2B, 2C, 2D, 3, and 4 (may be one vein) consisting of plagioclase plus green amphibole.



### 118-735B-81R-3

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-5H

### Metagabbro

### Pieces 1A-5F (top)

**COLOR:** Greenish gray.
**LAYERING:** None. Variations in grain size: Piece 4B is coarse-grained (>1.5 cm).
**DEFORMATION:** Foliation apparent in Pieces 1A, 1B, 3A, 3C, 3D, and 4A. Discrete mylonitic zones with crushed pyroxenes and albitized plagioclase in Pieces 1B and 3A-3D.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 0.5-1.0 cm.
Crystal shape: Subhedral.
Preferred orientation: None observed.
Percent replacement: 0%-10% by sodic plagioclase.

Clinopyroxene—Mode: 48%.
Crystal size: 1-2 cm.
Crystal shape: Poikilitic.
Preferred orientation: None observed.
Percent replacement: Up to 15% by amphibole.

Olivine—Mode: 2%.
Crystal size: Variable, 0.5-1.5 cm (increases toward Piece 5).
Crystal shape: Anhedral.
Preferred orientation: None observed.
Percent replacement: <1% by chlorite.

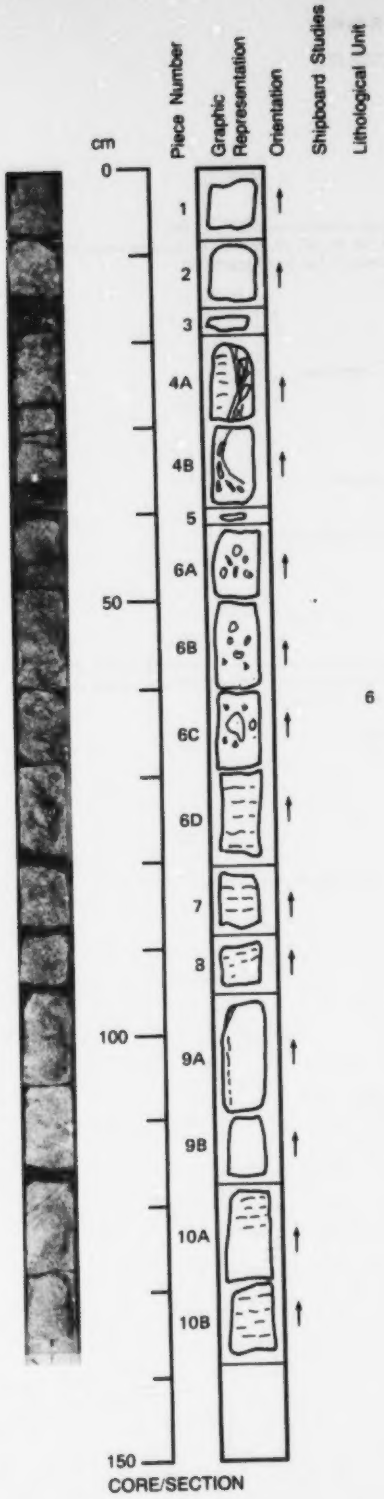
**SECONDARY MINERALOGY:**
Total percent: Up to 15%.
Texture: Distinct amphibole halos around clinopyroxene, white albitized zones at 5, 80, 87, and 110 cm. Small fractures filled with green amphibole. Black chlorite pseudomorphs alter olivine and clinopyroxene. Vein with albite (+quartz) in Piece 5D.
Percent vein material: 5%.
Vein material: Amphibole albite, and quartz.
**COMMENTS:** Disseminated sulfides throughout core.

### Leucotroctolite

### Pieces 5F (bottom) -5H

**COLOR:** Pale gray.
**LAYERING:** Weak magmatic foliation suggested by elongation of the olivine.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 70%.
Crystal size: 2-3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Plagioclase is albitized.

Olivine—Mode: 30%.
Crystal size: 0.5-1.5 cm.
Crystal shape: Subhedral.
Preferred orientation: Elongation, subparallel.
Percent replacement: <5% by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Olivine replaced by amphibole.
Percent vein material: None.
Vein material: None.



### 118-735B-81R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-10B**

### Olivine Gabbro

**Pieces 1, 3, 4A, 5, and 6D-10B**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** Weak except when in contact with oxide gabbro.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 3-10 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 35%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral-euhedral. Subophitically encloses plagioclase.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: 2-8 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Olivine veined with magnetite. Clinopyroxene is greenish when fresh and pinkish when altered. Pinkish clinopyroxene rims around greenish cores. Pinkish areas are sometimes surrounded by black or dark green amphibole.
Percent vein material: Not determined.
Vein material: Not determined.

### Oxide-Rich Olivine Gabbro

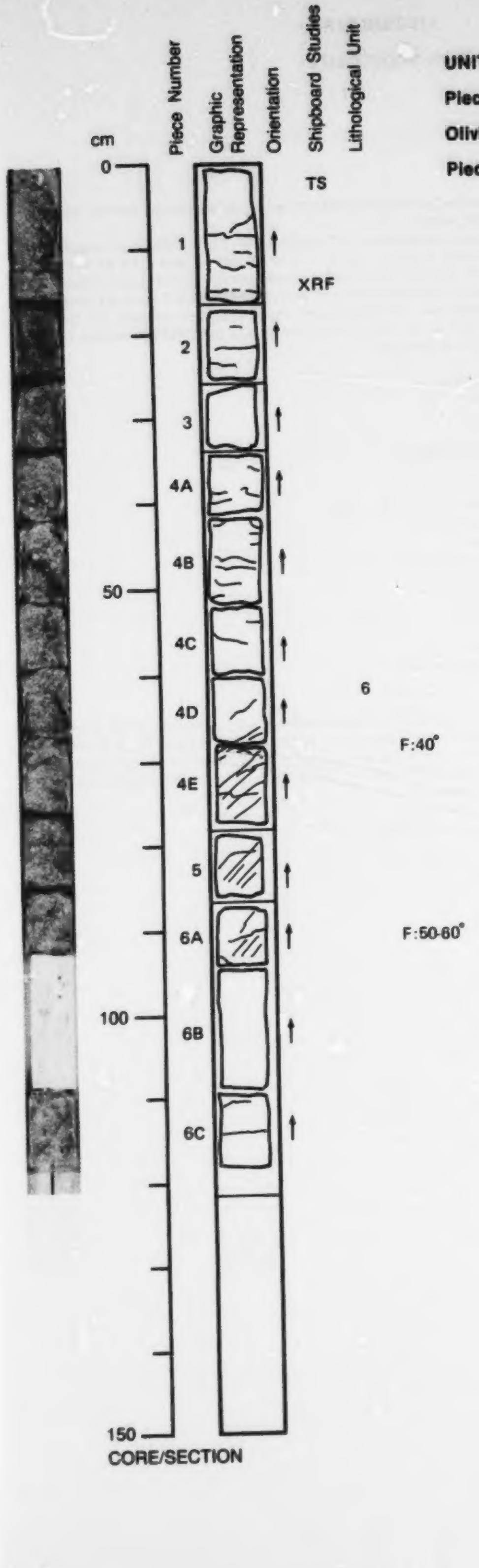
**Pieces 2, 4A, 4B, and 6A-6C**

**COLOR:** Greenish gray.
**LAYERING:** None.
**DEFORMATION:** Strongly foliated in places and porphyroclastic with stretched olivine, pyroxene, and plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 15%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 25%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium Oxide—Mode: 10% as fine-grained aggregates.
Sulfides—Mode: Trace as blebs and fine grained intergrowths with oxide.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Amphibole replacing clinopyroxene, oxide replacing olivine, but much olivine is fresh.
Percent vein material: Not determined.
Vein material: Not determined.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1
2
3
4A
4B
4C
4D
4E
5
6A
6B
6C
TS
XRF
6
F:40°
F:50-60°

**118-735B-81R-5**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-6C**

**Olivine Gabbro**

**Pieces 1-6C**

**COLOR:** Gray.

**LAYERING:** Weak layering defined by grading in grain size. In general, the section is medium-grained (0.5-1.5 cm).

**DEFORMATION:** Foliation grading into mylonitic bands to be seen in Pieces 4D, 4E, 5, and 6A. Inclination 40°-60°. In other pieces, no apparent deformation.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-60%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Pyroxene—Mode: 30%-40%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: <10% by amphibole.

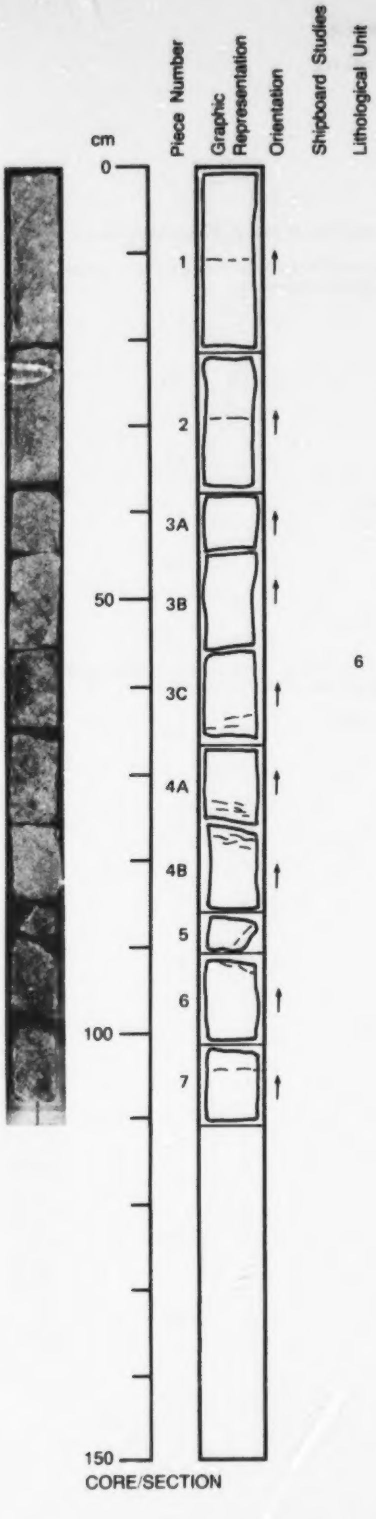
Olivine—Mode: 5%-15%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight alteration.
Texture: Amphibole replacement of pyroxene (<10%), olivine partially replaced by talc(?).
Percent vein material: Few subhorizontal veinlets with white minerals.
Vein material: Not determined.

**COMMENTS:** Sulfides disseminated throughout section.

**118-735B-81R-6**



## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-7

### Olivine Two-Pyroxene Gabbro

### Pieces 1-7

**COLOR:** Gray on cut surface, speckled green and pinkish brown or white on cored surface. Slightly green with amphibole near veins.

**LAYERING:** Two sequences of fine to coarse grain size variation with slight increase in proportion of mafic phases in coarse zones (coarse = up to 1 cm in Pieces 1, 6, and 7; 1.5 cm in Piece 3C; fine = 0.25-0.5 cm in rest). Some approximately flat orientation of pyroxenes in Piece 1.

**DEFORMATION:** Some thin horizontal fractures shown by dashed lines. Piece 5 has a plagioclase + amphibole vein on one edge with collection quality green amphibole crystals. The top of Piece 4B is slightly granulated and veined with a fine white mineral (amphibole?). Bottom of Piece 4A has many nearly horizontal fractures.

**PRIMARY MINERALOGY:**

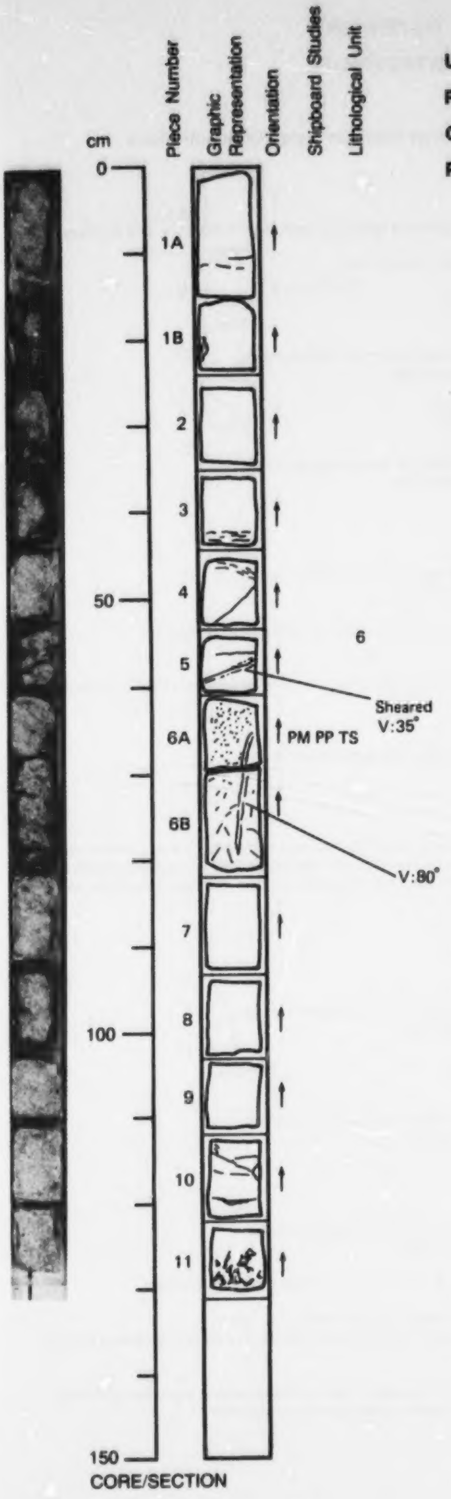
Plagioclase—Mode: 45%-60%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 15%-30%.
Crystal size: 0.2-0.5 cm with some up to 1.5 cm.
Crystal shape: Euhedral, subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: Trace-2%.
Crystal size: Not determined.
Crystal shape: Euhedral.
Preferred orientation: None.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Slight.
Texture: Green amphibole in fracture, Piece 5; pervasive in slight amounts. Fairly abundant (5-10%) in Pieces 3C-4B. Sodic plagiolcase zones in Piece 5 and at top of Piece 6. Patchy ilmenite/magnetite zone in Pieces 3C-4B along zones of shearing or fracturing; present in trace amounts in Piece 1. Portions of Pieces 2 and 3 are quite fresh. Minor pyrite and chalcopyrite associated with ilmenite.
Percent vein material: Not determined.
Vein material: Amphibole and plagioclase.



**118-735B-81R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-11

### Olivine Gabbro with Iron-Titanium Oxide-Rich Gabbro

### Pieces 1A-11

**COLOR:** Gray, greenish gray where amphibole is present.

**LAYERING:** Size and modal layering. Pieces 1A-5: medium-grained, subophitic; olivine: 10%, 1-2 mm, average 5 mm; clinopyroxene: 30%, 2-15 mm, average 7 mm; plagioclase: 60%, 3-20 mm, average 10 mm. Pieces 6A-6B: graded layer; olivine: 5%-7%, top average 0.5 mm, bottom average 5 mm; clinopyroxene: 30%-25%; top average 1 mm, bottom average 10 mm; plagioclase: 60%, top average 3 mm, bottom average 15 mm. Pieces 7-10: medium-grained, subophitic, similar to Pieces 1A-5. Piece 11: iron-titanium oxide gabbro, olivine: 1%, average 7 mm; clinopyroxene: 20%, average 10 mm; plagioclase: 60%, average 12 mm; opaque: 15%, average 7 mm.

**DEFORMATION:** Sheared zones, 1-2 cm thick are present in Pieces 2, 3, 5, 6A, and 6B. The zone in Piece 5 is mylonitic. They incline variously from 30°-80°.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 60%.
Crystal size: 3-20 mm.
Crystal shape: Euhedral to subhedral.
Preferred orientation: Not clear.
Percent replacement: None.

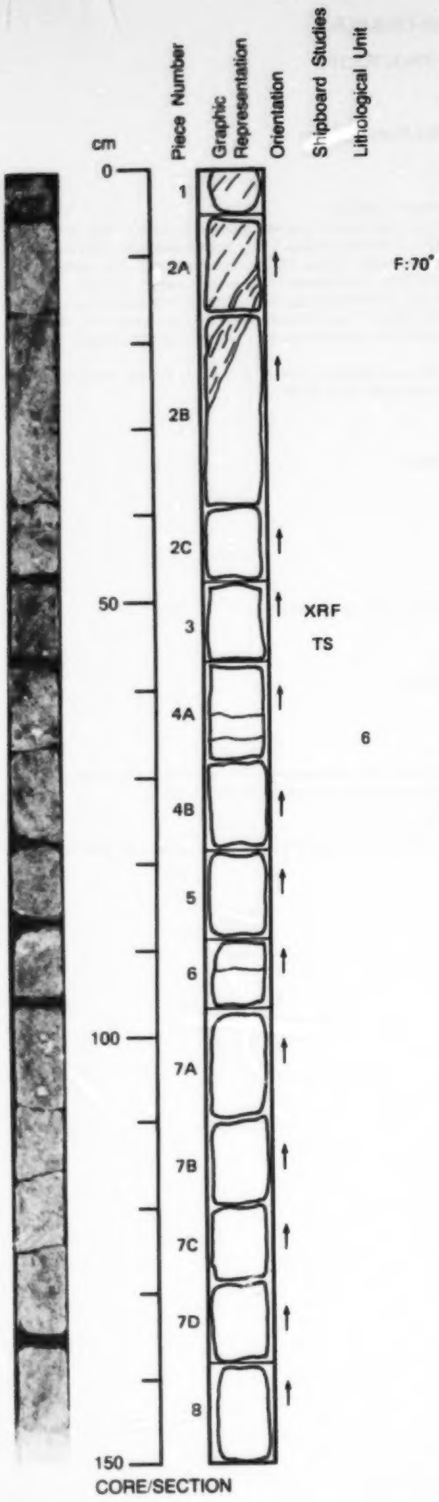
Clinopyroxene—Mode: 30%.
Crystal size: 2-11 mm.
Crystal shape: Anhedral.
Preferred orientation: Not clear.
Percent replacement: 5-10%, locally >15% by amphibole.

Olivine—Mode: 10%.
Crystal size: 2-7 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: Not clear.
Percent replacement: Trace.

**SECONDARY MINERALOGY:**

Total percent: 10%.
Texture: Amphibole after clinopyroxene, 5%-10% generally, it is more than 15% locally as in Piece 11. Albitized and amphibolitized pockets are present in Pieces 1B-10.
Percent vein material: Trace, local.
Vein material: Amphibole vein in Piece 10.

**COMMENTS:** Grading in Pieces 6A-6B shows horizontal variation. The cored surface of Piece 6A is locally coarse-grained.



**118-735B-82R-1**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-8**

### Poorly Foliated Olivine Gabbro with Iron-Titanium Oxide Concentrations

**Pieces 1-2B**

**COLOR:** Gray green.
**LAYERING:** 3 cm-thick iron-titanium oxide-rich layer (5%), parallel to foliation, marks the base of the deformed zone.
**DEFORMATION:** Poorly defined foliation, with 70° dip.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-70%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Clinopyroxene—Mode: 5%-20%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Olivine—Mode: 5%-15%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Iron-titanium oxide—Mode: Up to 6% in poorly foliated Pieces 2A and 2B.
**SECONDARY MINERALOGY:**
Total percent: <20%.
Texture: Amphibole replaces clinopyroxene and olivine. Plagioclase is slightly albitized.
Percent vein material: <1%.
Vein material: Not determined.

### Olivine Gabbro with Iron-Titanium Oxide Concentrations

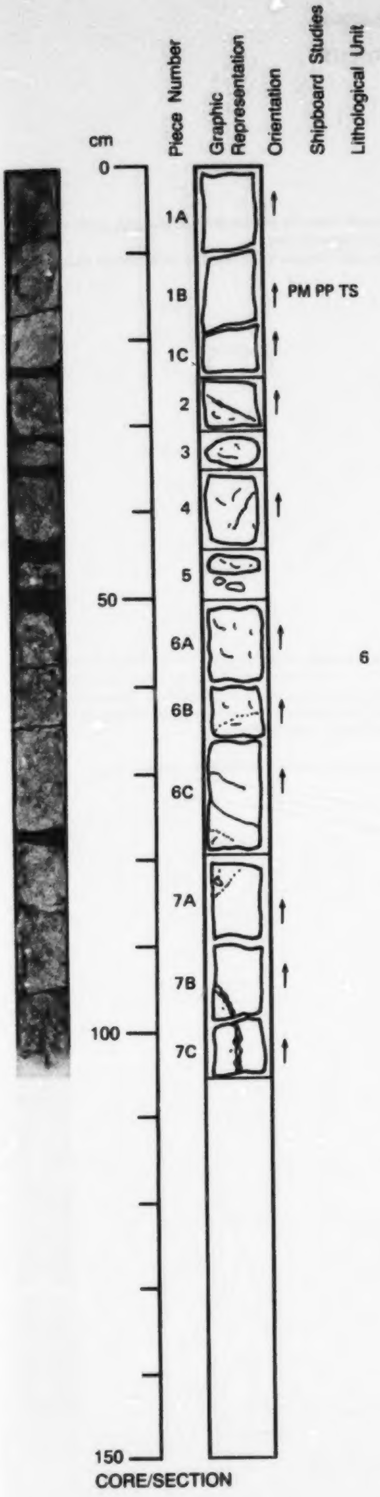
**Pieces 2B-8**

**COLOR:** Gray green.
**LAYERING:** Grain size variations: <2 cm in Piece 2B; <3 cm in Piece 2C; <1 cm in Pieces 3-8. The contact between the coarse grained gabbro of Piece 2C and the fine-grained gabbro below is subhorizontal. Modal variations: not clear. Pyroxene is brown in Pieces 2B and 2C, and green in Pieces 3-8.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-70%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Clinopyroxene—Mode: 5%-20%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Olivine—Mode: 5%-15%.
Crystal size: <1-3 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in poorly foliated pieces.
Percent replacement: Not determined.

Iron-titanium oxide—Mode: Up to 6% in poorly foliated Pieces 2A and 2B.
**SECONDARY MINERALOGY:**
Total percent: Slight except in Pieces 4A and 6 where it is >20%.
Texture: Amphibole replaces the clinopyroxene and olivine. Plagioclase is slightly albitized.
Percent vein material: <1%.
Vein material: No visible veins.
**COMMENTS:** Clear-cut transition at 48 cm between brown pyroxene-bearing and green pyroxene-bearing gabbro. Color change may be primary or due to alteration.



**118-735B-82R-2**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-7C**

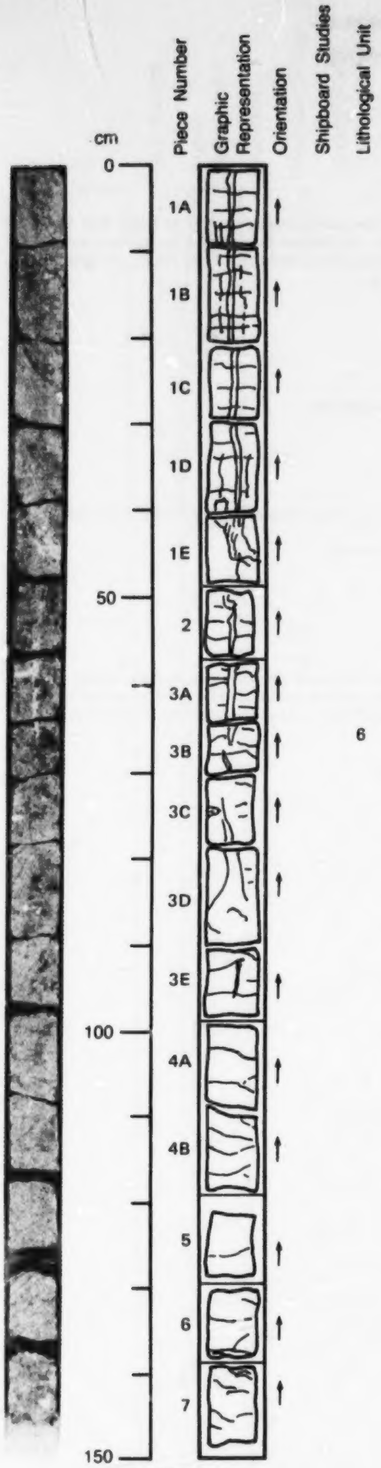
**Olivine Gabbro**

**Pieces 1A-7C**

**COLOR:** Gray.
**LAYERING:** Grain size variations: Pieces 1A-2 are fine-grained (average <0.5 cm). Pieces 2-6B are pegmatoidal (average >3 cm) hornblende + plagioclase. Pieces 6C-7B are coarse-grained (average >1.5 cm). Pieces 7B-7C are coarse-grained (average >2 cm). Abrupt changes appear hydrothermal in origin.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Variable; see above.
Crystal shape: Subhedral.
Preferred orientation: None observed.
Percent replacement: 0%-20% by sodic plagioclase.

Clinopyroxene—Mode: 40%-50%.
Crystal size: Variable; see above.
Crystal shape: Poikilitic.
Preferred orientation: None observed.
Percent replacement: 0%-20% by amphibole; more replacement in coarse-grained portions.

Olivine—2%-5% greater near bottom of section.
Crystal size: Varible; see above.
Crystal shape: Rounded.
Preferred orientation: None observed.
Percent replacement: None.
**SECONDARY MINERALOGY:**
Total percent: 0%-20%.
Texture: Abundant (up to 20%) amphiboles, replacing clinopyroxene. Pyroxene altered to pinkish color. Plagioclase is albitized. Pegmatoidal gabbro appears to be large hornblende-plagioclase vein with large euhedral plagioclase (2 cm) and hornblendes (2 cm) growing perpendicular to sides.
Percent vein material: 5%.
Vein material: Amphibole and plagioclase.
**COMMENTS:** Disseminated sulfides.



**118-735B-82R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-7**

**Olivine Gabbro**

**Pieces 1A-7**

**COLOR:** Gray to greenish gray.

**LAYERING:** Not very pronounced, if any. Rock is predominantly coarse grained (average grain size between 1.0 and 2.0 cm) with some less coarse intervals.

**DEFORMATION:** Pieces 3E-7F appear to be undeformed. Pieces 1A-3D exhibit deformation along major vein, i.e. almost vertical.

**PRIMARY MINERALOGY:**

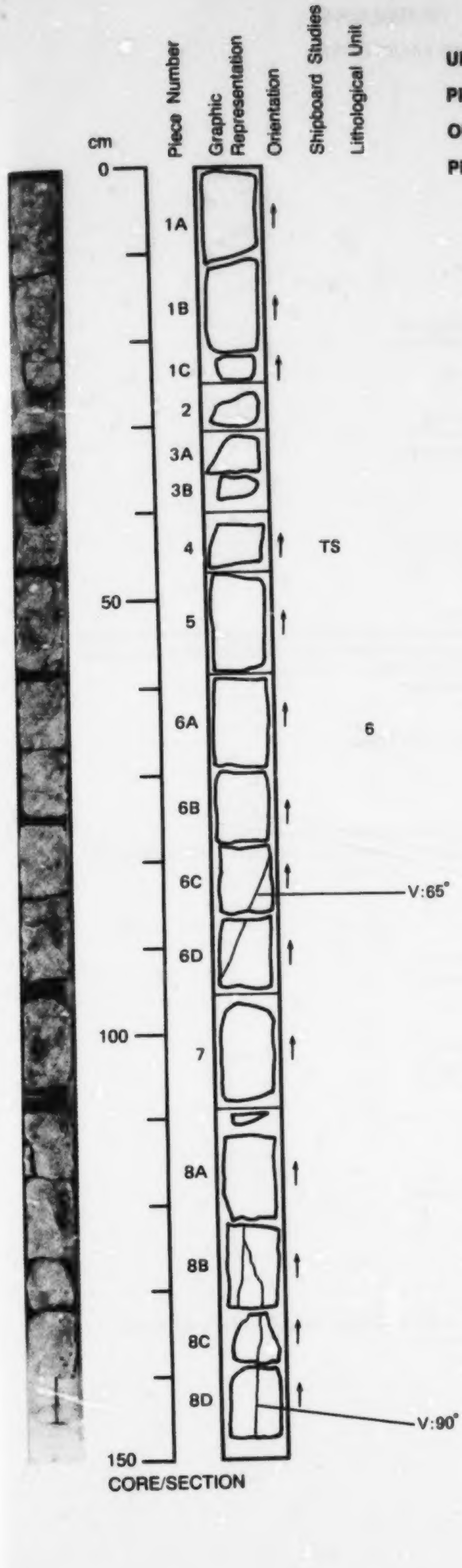
Plagioclase—Mode: 50%-60%.
Crystal size: 1-2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 0.5-2.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: Moderately altered.
Texture: Section is moderately altered and intensely veined (Pieces 1A-3E). There is one major, almost vertical vein from Pieces 1A-3B, up to 1 cm across, and filled with iron-titanium oxides (Pieces 1A-1D). This vein is older than the numerous subhorizontal veinlets (filled with white minerals) and also older than the albite and amphibole vein continuing on Pieces 1D-3D. Satellite veins with sulfides, especially well developed on Piece 1D.
Percent vein material: Not determined.
Vein material: Iron-titanium oxides, white minerals, albite, amphibole, and sulfides.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
2
3A
3B
4
5
6A
6B
6C
6D
7
8A
8B
8C
8D
TS
6
V:65°
V:90°
CORE/SECTION

**118-735B-82R-4**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-8D**

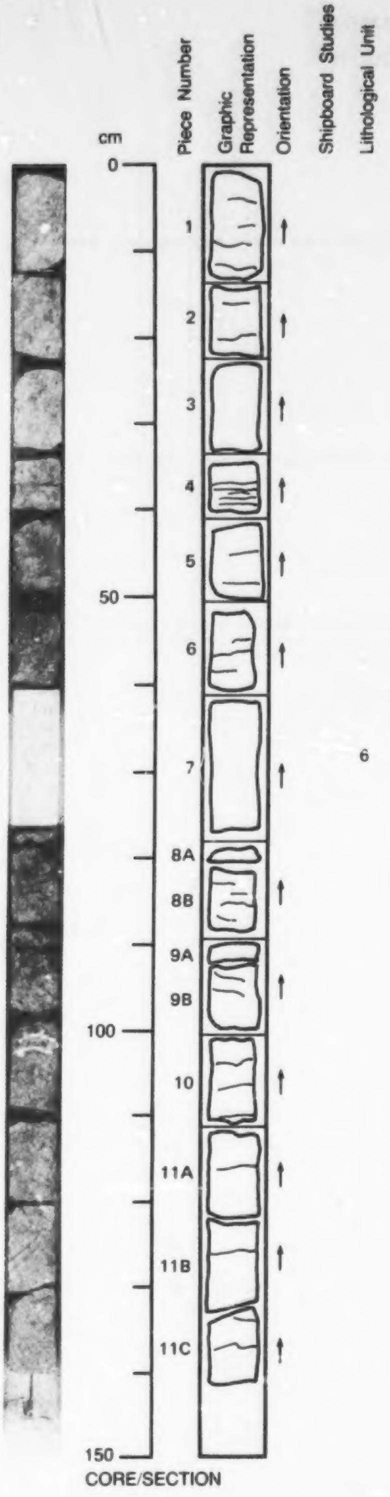
**Olivine Gabbro**

**Pieces 1A-8D**

**COLOR:** Gray.
**LAYERING:** No apparent layering.
**DEFORMATION:** No deformation except in Pieces 8B-8D where sheared amphibole vein is present.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 3-40 mm.
Crystal shape: Anhedral to subhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 25%-30%.
Crystal size: 2-30 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: <5% generally by amphibole, but up to 20% where veined.

Olivine—Mode: 15%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None.
Percent replacement: None or trace by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <3%, locally up to 10%.
Texture: Amphibole replacing clinopyroxene approximately 5% generally, but the amount increases up to 20% in veined or sheared portions such as Pieces 8B-8D. In these portions olivine is altered into pale green mineral (tremolite?).
Percent vein material: Trace.
Vein material: Amphibole and albite filled cracks occur in Pieces 6C and 6D.
**COMMENTS:** Coarse grained subophitic.



**118-735B-82R-5**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-11C

### Olivine Gabbro

### Pieces 1-4

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral-subhedral
Percent replacement: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Percent replacement: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**
Total percent: Moderate alteration.
Texture: Intense amphibole replacement (up to 50%), olivine sometimes with preserved fresh core. Few subhorizontal white veinlets. Pieces 2 and 4 are extensively altered. Lower half of Piece 4 strongly mylonitized (subhorizontal deformation bands).
Percent vein material: Not determined.
Vein material: Not determined.

### Foliated Iron-Titanium Oxide-Rich Olivine Gabbro

### Pieces 5-11C

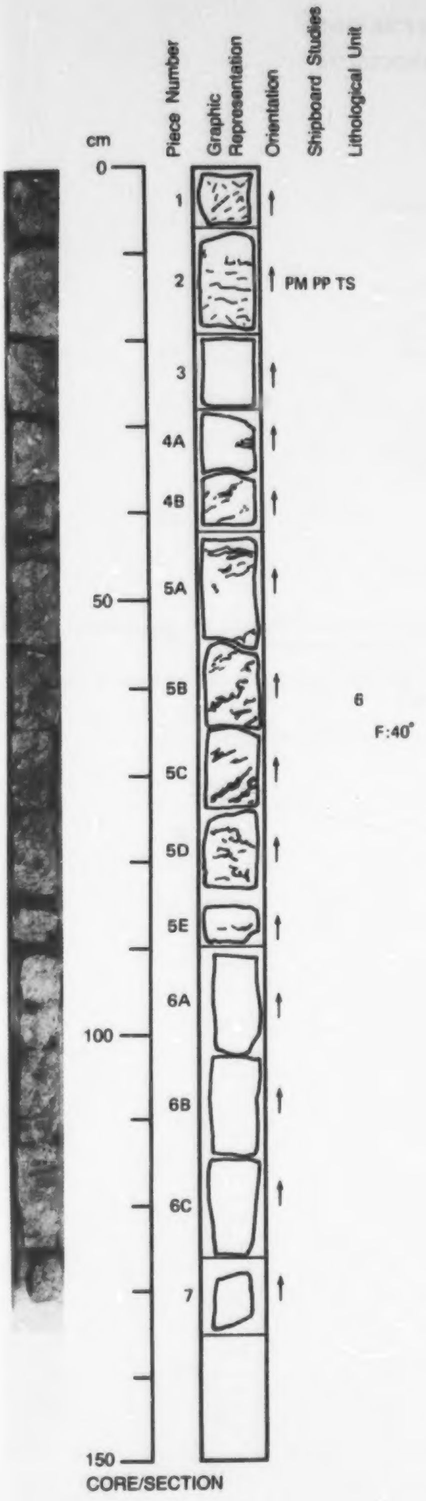
**COLOR:** Medium to dark gray.
**LAYERING:** None apparent. Medium- to coarse-grained (1 cm).
**DEFORMATION:** Strong foliation, defined by stretched plagioclase, olivine, and clinopyroxene. Iron-titanium oxides form layers (deformation layers?).
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 30%-50%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: Up to 2 cm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 10%-20%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Iron-titanium oxides—Mode: 10%-25%

Sulfides—Mode: <1%.
**SECONDARY MINERALOGY:**
Total percent: Moderately altered.
Texture: Rocks are moderately altered. Amphibole replacement (50% and more).
Percent vein material: Not determined.
Vein material: Not determined.



## 118-735B-82R-6

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-7**

### Iron-Titanium Oxide Gabbro

**Pieces 2 and 4A-5F**

**COLOR:** Greenish gray with black streaks.
**LAYERING:** None apparent. Foliation defined by elongated clinopyroxene and oxide minerals is marked. It dips 40°.
**DEFORMATION:** Locally porphyroclastic. Plagioclase is recrystallized into smaller grains. Locally undeformed portion remains.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%-60%.
Crystal size: Not determined.
Crystal shape: Anhedral.
Preferred orientation: Apparent.
Percent replacement: None.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 5-20 mm.
Crystal shape: Subhedral, anhedral.
Preferred orientation: Apparent.
Percent replacement: 10%-20% by amphibole.

Olivine—Mode: <3%.
Crystal size: 5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not apparent.
Percent replacement: Not clear.

Iron-titanium oxide—Mode: 5%-15%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral.
Preferred orientation: Marked.
Percent replacement: None.
**SECONDARY MINERALOGY:**
Total percent: 10%.
Texture: Amphibole replacing clinopyroxene, 10-20%.
Percent vein material: None.
Vein material: None.

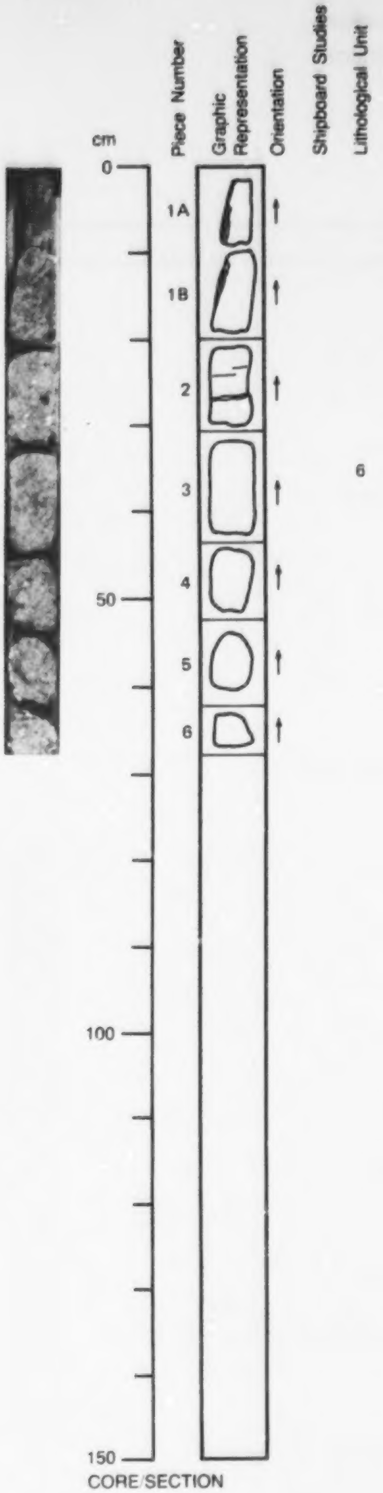
### Olivine Gabbro

**Pieces 1, 3, and 6A-7**

**COLOR:** Gray.
**LAYERING:** No layering.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 10-20 mm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: None.

Clinopyroxene—Mode: 25%.
Crystal size: 3-20 mm. Most clinopyroxene is oikocrystic up to 10-20 mm across.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Trace by amphibole.

Olivine—Mode: 15%.
Crystal size: 3-13 mm.
Crystal shape: Subhedral-anhedral.
Preferred orientation: None.
Percent replacement: Trace by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <3%.
Texture: Amphibole replacing clinopyroxene and olivine approximately 5%.
Percent vein material: None.
Vein material: None.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2
3
4
5
6
6
CORE/SECTION

**118-735B-82R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-6**

**Olivine Gabbro**

**Pieces 1A-6**

**COLOR:** Gray.
**LAYERING:** None apparent.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-55%.
Crystal size: 3-20 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%.
Crystal size: 3-15 mm.
Crystal shape: Subhedral, oikocrystic.
Preferred orientation: Not determined.
Percent replacement: Not determined

Olivine—Mode: 5%-10%.
Crystal size: 3-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 10%-15%.
Texture: Clinopyroxene partly altered to amphibole. Olivine altered to magnetite (mesh texture) plus tremolite(?). Narrow rims around olivine pseudomorphs (chloritic?).
Percent vein material: Not determined.
Vein material: White streaks (<1.5 mm veins) common. Vein on surface Pieces 1A and 1B contains tremolite-actinolite + talc(?).

**COMMENTS:** Pyroxene is often green with pinkish rim or entirely pinkish.

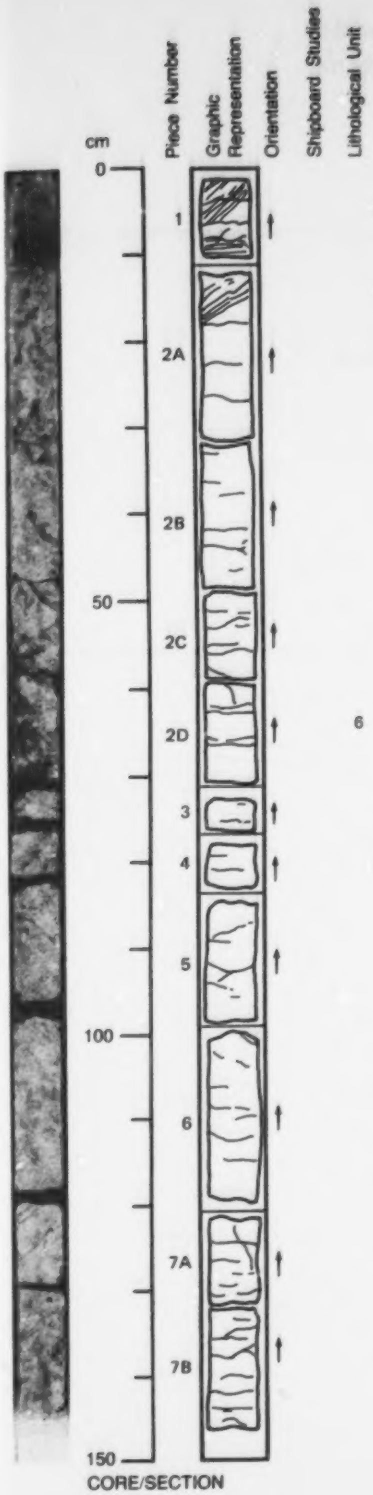
**118-735B-83R-1**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-7B**

**Olivine Gabbro**

**Pieces 1-7B**



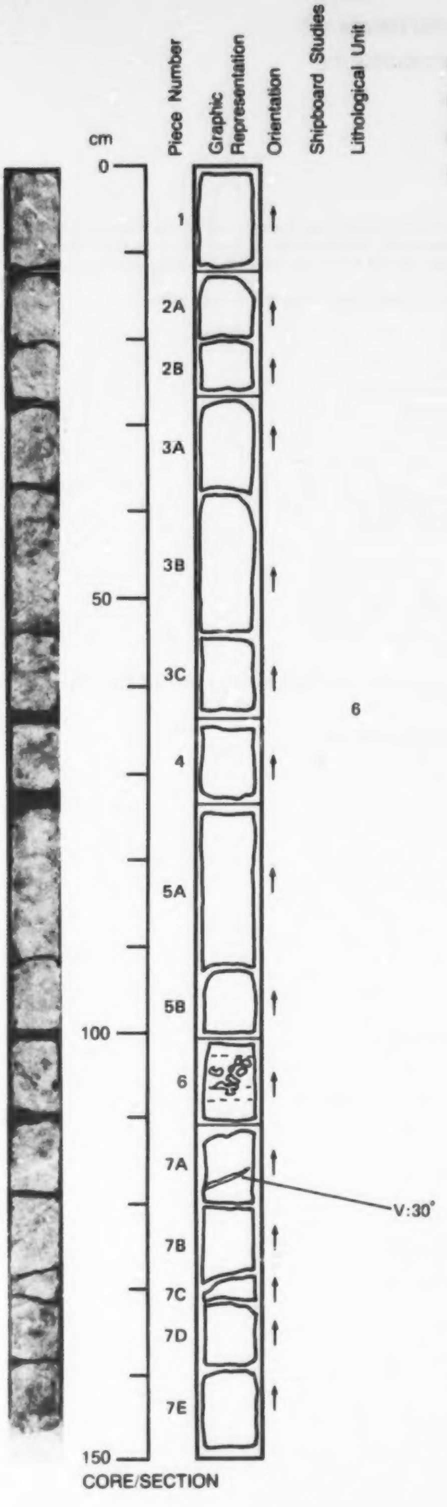
F:25-30°

F:30-35°

**COLOR:** Gray.
**LAYERING:** Weak layering indicated by grading in grain size. Possibly two "cycles" each from medium- to coarse-grained to very coarse-grained. Interval 20-62 cm: increase in size from 1-2 cm on average to 1.5-2.5 cm on average; interval 62-147 cm: increase in average grain size from 1.0 cm to 1.5-2.5 cm (Piece 7).
**DEFORMATION:** Poorly defined foliation in Piece 1. No deformation in other pieces.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Not determined.
Preferred orientation: None except in Piece 1.
Percent replacement: None apparent.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 3 cm.
Crystal shape: Not determined.
Preferred orientation: None except in Piece 1.
Percent replacement: <10% by amphibole.

Olivine—Mode: <10%-20%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None except in Piece 1.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: <15%.
Texture: Amphibole replaces clinopyroxene and olivine, some talc also replaces olivine. The plagioclase is not visibly albitized.
Percent vein material: <1%.
Vein material: Very thin subhorizontal white veins.
**COMMENTS:** The clinopyroxene is brownish.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
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100
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2B
3A
3B
3C
4
5A
5B
6
7A
7B
7C
7D
7E
6
V:30°
CORE/SECTION

**118-735B-83R-2**

**UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE**

**Pieces 1-7E**

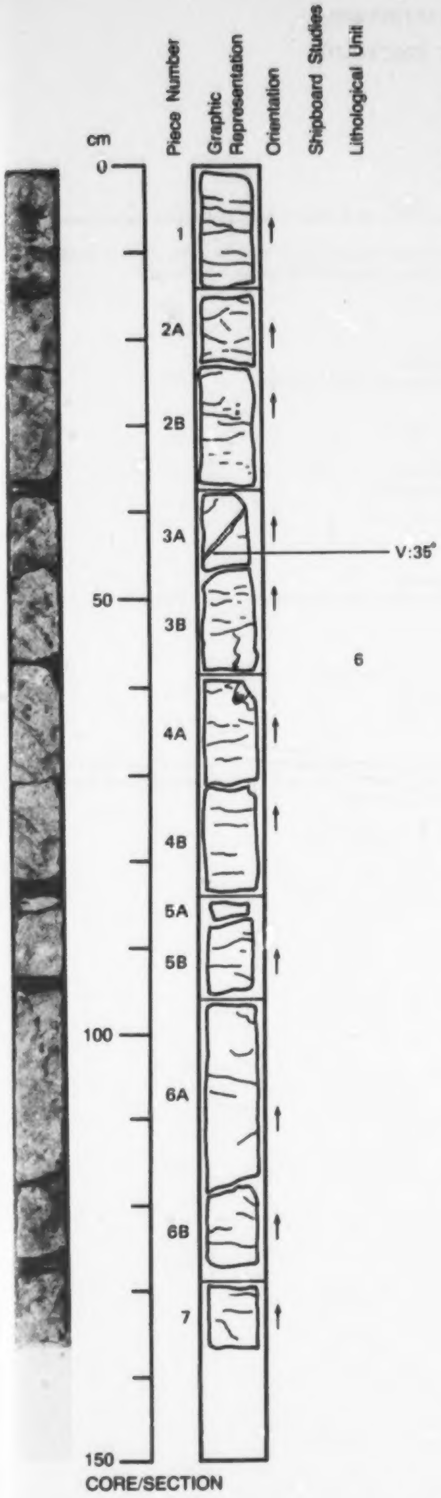
**Olivine Gabbro**

**Pieces 1-7E**

**COLOR:** Gray.
**LAYERING:** There are modal variations, suggesting layering. Piece 6 has an olivine-rich layer. No apparent size variation.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 5-20 mm, (average 10 mm).
Crystal shape: Euhedral.
Preferred orientation: Slight, 10°-20° inclining.
Percent replacement: None.

Clinopyroxene—Mode: 10%-30%.
Crystal size: 5-30 mm (average 15 mm).
Crystal shape: Anhedral, oikocrystic (e.g., Piece 6).
Preferred orientation: Not clear.
Percent replacement: 5% by amphibole.

Olivine—Mode: 10%-25%.
Crystal size: 5-20 mm, (average 10 mm).
Crystal shape: Anhedral, oikocrystic (e.g., Piece 6).
Preferred orientation: Not clear.
Percent replacement: 5% by tremolite.
**SECONDARY MINERALOGY:**
Total percent: 5%.
Texture: Amphibole replacing clinopyroxene and olivine 5%. Olivine has white veins of tremolite and mica or talc.
Percent vein material: Trace.
Vein material: Plagioclase.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
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1
2A
2B
3A
3B
4A
4B
5A
5B
6A
6B
7
V:35°
6
CORE/SECTION

### 118-735B-83R-3

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-7**

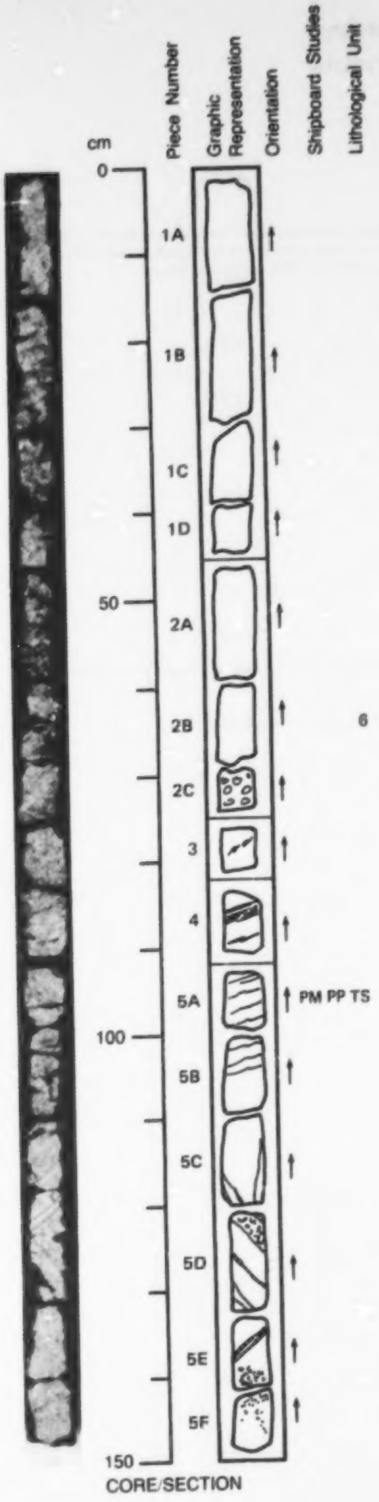
**Olivine Gabbro**

**Pieces 1-7**

**COLOR:** Gray.
**LAYERING:** Only faintly developed. Small changes in grain size, from medium-grained (very top Piece 1, 0.5-1.0 cm), over coarse-grained (1.5-2.5 cm, most pieces) to very coarse-grained (2.5 cm). Probably some phase layering, olivine enrichment between 48 and 72 cm.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 3 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-20%.
Crystal size: Up to 2.5 cm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Slight.
Texture: Amphibole replacement of clinopyroxene (< 10%). Olivine shows rims of talc + tremolite(?). Few sulfides.
Percent vein material: 3%-4%.
Vein material: Veins with plagioclase and amphibole (Pieces 3A and 4A).


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
1C
1D
2A
2B
2C
3
4
5A
5B
5C
5D
5E
5F
PM PP TS
6
CORE/SECTION

118-735B-83R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-5F**

**Olivine Gabbro**

**Pieces 1A-5F**

**COLOR:** Light gray.

**LAYERING:** Size grading, coarsening from Piece 1A to Piece 3. Average pyroxene size increases from 5 to 15 mm.

**DEFORMATION:** Localized shear zones (Pieces 5A and 5B) and mylonite zones (Piece 4). Gradient in deformation from mylonitized gabbro to undeformed gabbro in Pieces 4-5B.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 55%-65%.
Crystal size: 3-20 mm.
Crystal shape: Subhedral-euhedral.
Preferred orientation: None apparent.
Percent replacement: 30%-50% by secondary plagioclase.

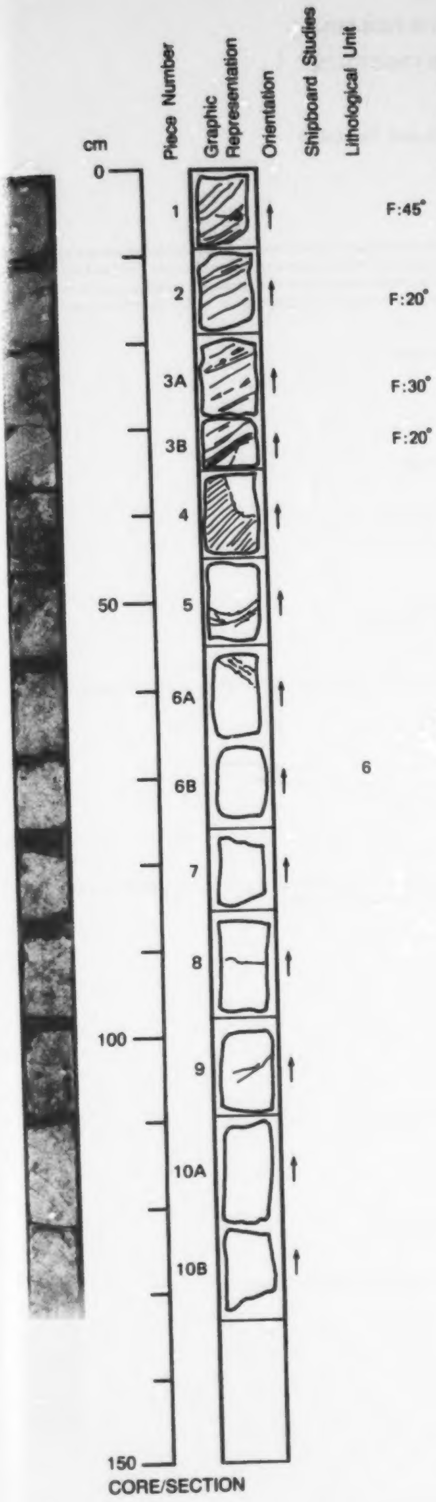
Clinopyroxene—Mode: 35%.
Crystal size: 3-20 mm.
Crystal shape: Subophitic.
Preferred orientation: None apparent.
Percent replacement: 30% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None apparent.
Percent replacement: 30% by magnetite and tremolite with rims of chlorite(?).

Iron-titanium oxide—Mode: Trace.
Crystal size: Not determined.
Crystal shape: Fine-grained interstitial aggregate.
Preferred orientation: None apparent.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 20%.
Texture: Olivine replaced by meshwork of magnetite + tremolite. Rim of chloritic(?) material around relicts and pseudomorphs. Clinopyroxene partly replaced by amphibole. Iron-titanium oxide most common in coarse-grained Piece 3.
Percent vein material: 1%-2%.
Vein material: Veins of amphibole in Pieces 5C-5E.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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3A
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10A
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F:45°
F:20°
F:30°
F:20°
6
CORE/SECTION

## 118-735B-83R-5

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-10B**

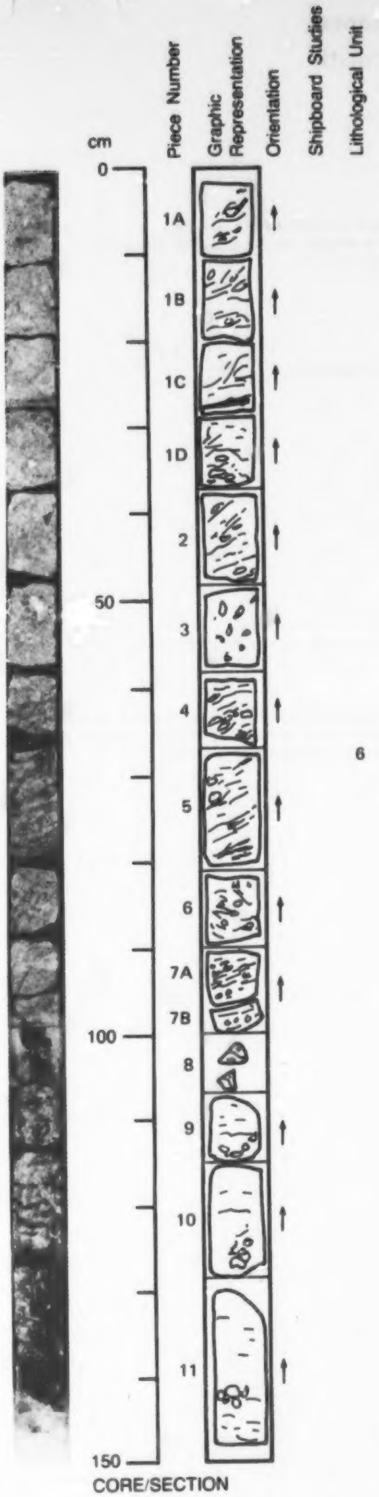
**Olivine Gabbro**

**Pieces 1-10B**

**COLOR:** Brownish gray.
**LAYERING:** Some modal variations: felsic-rich regions in Pieces 3B, 4, and 7A.
**DEFORMATION:** Mylonite bands rich in opaques in Pieces 2, 3A, 3B, 5, and 6A. Piece 1 is porphyroclastic, but lacks ore enrichment.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-70%.
Crystal size: 0.5-1 cm.
Crystal shape: Subhedral to poikilitic.
Preferred orientation: None observed.
Percent replacement: 10%-15% by sodic plagioclase.

Clinopyroxene—Mode: 15%-20%.
Crystal size: 0.5-2 cm.
Crystal shape: Large oikocrysts.
Preferred orientation: None observed.
Percent replacement: 15% by amphibole.

Olivine—Mode: 15%-30%.
Crystal size: <1 cm.
Crystal shape: Rounded.
Preferred orientation: None observed.
Percent replacement: Minor.
**SECONDARY MINERALOGY:**
Total percent: 15%-30%.
Texture: Plagioclase is altered to sodic plagioclase. Up to 15% of clinopyroxene is altered to green amphibole.
Percent vein material: <5%.
Vein material: Amphibole.
**COMMENTS:** Pieces 1-6A are foliated. Magnetite/ilmenite in foliation plane in Pieces 2, 3A and 3B and in deformed lenses in Piece 5. Disseminated sulfide, some intergrown with opaques. Massive ore enrichment zone with sheared contact against felsic gabbro in Piece 4.



118-735B-83R-6

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-11

### Undeformed-Deformed Olivine Gabbro and Troctolite

### Pieces 1A-2, and 4-8

**COLOR:** Greenish gray.
**LAYERING:** None apparent.
**DEFORMATION:** 5- to 15-mm-sized clinopyroxene and plagioclase porphyroclasts are remarkably visible especially in Pieces 1A-1C. Opaque- and plagioclase-rich mylonitic layer defines foliation, which inclines 10°. There is undeformed olivine gabbro in between porphyroclastic ones. Porphyroclast size is small in Pieces 7A and 7B, which are just above troctolite layer.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 60%.
Crystal size: 5-15 mm (porphyroclast).
Crystal shape: Anhedral.
Preferred orientation: Apparent.
Percent replacement: None.

Clinopyroxene—Mode: 30%.
Crystal size: 5-15 mm (porphyroclast).
Crystal shape: Anhedral.
Preferred orientation: Apparent.
Percent replacement: 15% by amphibole.

Olivine—Mode: 5%-10%.
Crystal size: <5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not observed.
Percent replacement: Replaced by amphibole.
**SECONDARY MINERALOGY:**
Total percent: 5%-10%.
Texture: Abundant amphibole replaces clinopyroxene (15%). Olivine is also altered into amphibole(?)
Percent vein material: None.
Vein material: None.

### Olivine Gabbro (Undeformed)

### Piece 3

**COLOR:** Gray, black-speckled (olivine).
**LAYERING:** Not clear.
**DEFORMATION:** Slight defomation of clinopyroxene and plagioclase can be seen. Slight foliation defined by the elongate clinopyroxene and plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 5 mm.
Crystal shape: Subhedral.
Preferred orientation: Apparent.
Percent replacement: None.

Clinopyroxene—Mode: 25%.
Crystal size: 7 mm.
Crystal shape: Anhedral.
Preferred orientation: Apparent.
Percent replacement: 10% by amphibole.

Olivine—Mode: 20%.
Crystal size: 5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Replaced by amphibole.
**SECONDARY MINERALOGY:**
Total percent: <5%.
Texture: Clinopyroxene and olivine replaced by amphibole (10%).
Percent vein material: None.
Vein material: None.

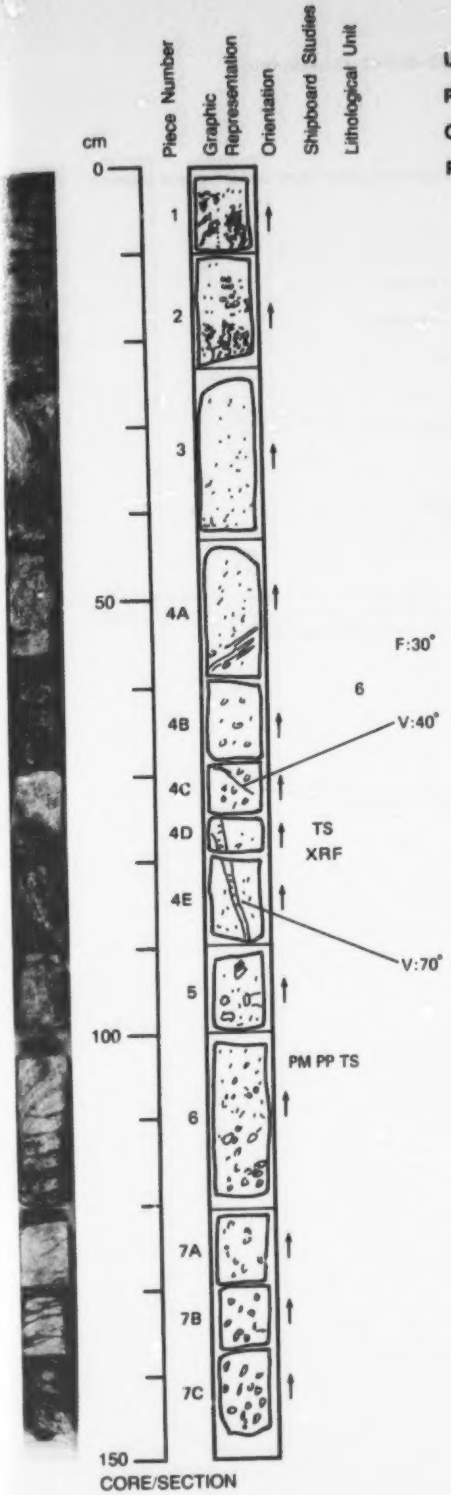
## 118-735B-83-7

## UNIT 8: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-7C**

**Olivine Gabbro**

**Pieces 1-7C**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Piece Number
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Orientation
Shipboard Studies
Lithological Unit
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7C
F:30°
V:40°
V:70°
6
TS
XRF
PM PP TS
CORE/SECTION

**COLOR:** Greenish gray, locally spotted where plagioclase is altered.

**LAYERING:** Size grading. In one graded unit, olivine varies from an average size of 2 mm in Piece 2 to an average size of 3 mm in Piece 4B. In another graded unit, olivine varies from an average size of 1 mm in Piece 5 to an average of 5 mm in Piece 7C.

**DEFORMATION:** Localized shear zone in Piece 4A.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 35%-60%.
Crystal size: 1-8 mm.
Crystal shape: Euhedral in plagioclase-rich zones, anhedral-interstitial in olivine-rich zones.
Preferred orientation: Not determined.
Percent replacement: 10-20%.

Clinopyroxene—Mode: 5%.
Crystal size: 25 mm.
Crystal shape: Oikocrystic.
Preferred orientation: Not determined.
Percent replacement: 10-20% by amphibole.

Olivine—Mode: 35%-60%.
Crystal size: 1-10 mm.
Crystal shape: Subhedral-anhedral in plagioclase-rich zones, euhedral in olivine-rich zones.
Preferred orientation: Not determined.
Percent replacement: 20% by magnetite, tremolite, and talc.

Spinel—Mode: Trace.
Crystal size: 0.5 mm.
Crystal shape: Euhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 20%.
Texture: Olivine veined with magnetite + tremolite + talc. Clinopyroxene partly replaced by amphibole.
Percent vein material: Not determined.
Vein material: Veins in Pieces 4C-4E contain tremolite and talc.

## 118-735B-83R-6 (continued)

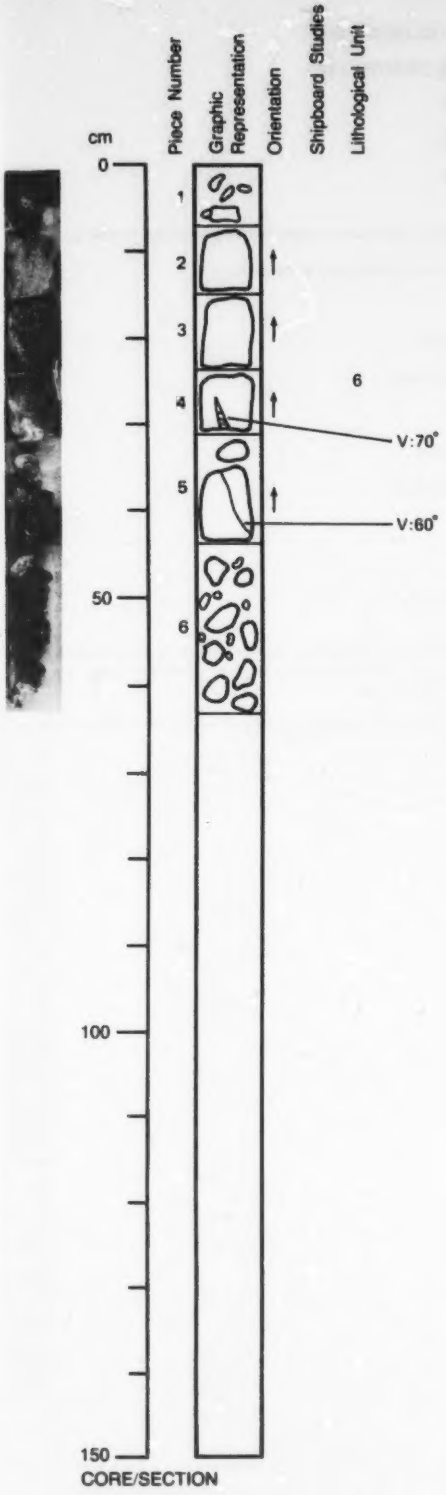
### Troctolite

### Pieces 9-11

**COLOR:** Black, speckled with white (plagioclase), green where clinopyroxene is present.
**LAYERING:** None apparent.
**DEFORMATION:** None apparent.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral and anhedral.
Preferred orientation: Not clear.
Percent replacement: 10% by amphibole.

Clinopyroxene—Mode: 5%-7%.
Crystal size: 20-30 mm.
Crystal shape: Anhedral, oikocrystic.
Preferred orientation: None.
Percent replacement: 10% by amphibole.

Olivine—Mode: 45%.
Crystal size: 2-10 mm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: Not clear.
Percent replacement: 20% by tremolite.
**SECONDARY MINERALOGY:**
Total percent: 10%-20%.
Texture: Olivine replaced by tremolite near vein. The cracks in olivine are filled by iron-titanium oxide. The cracks always incline 25°. Partly rich in amphibole. In Piece 11 (bottom), plagioclase is altered into milky, sodium-rich plagioclase.
Percent vein material: None.
Vein material: None.



**118-735B-83R-8**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-6

### Troctolite

### Pieces 1-4

**COLOR:** Greenish dark gray.
**LAYERING:** Not seen.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: <1 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: <1%.
Crystal size: 1-5 cm.
Crystal shape: Poikilitic.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 35%.
Crystal size: <1 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Relatively important alteration of olivine (rims of greenish minerals) especially developed in Piece 4 near the amphibole vein.
Percent vein material: <1%.
Vein material: Amphibole.

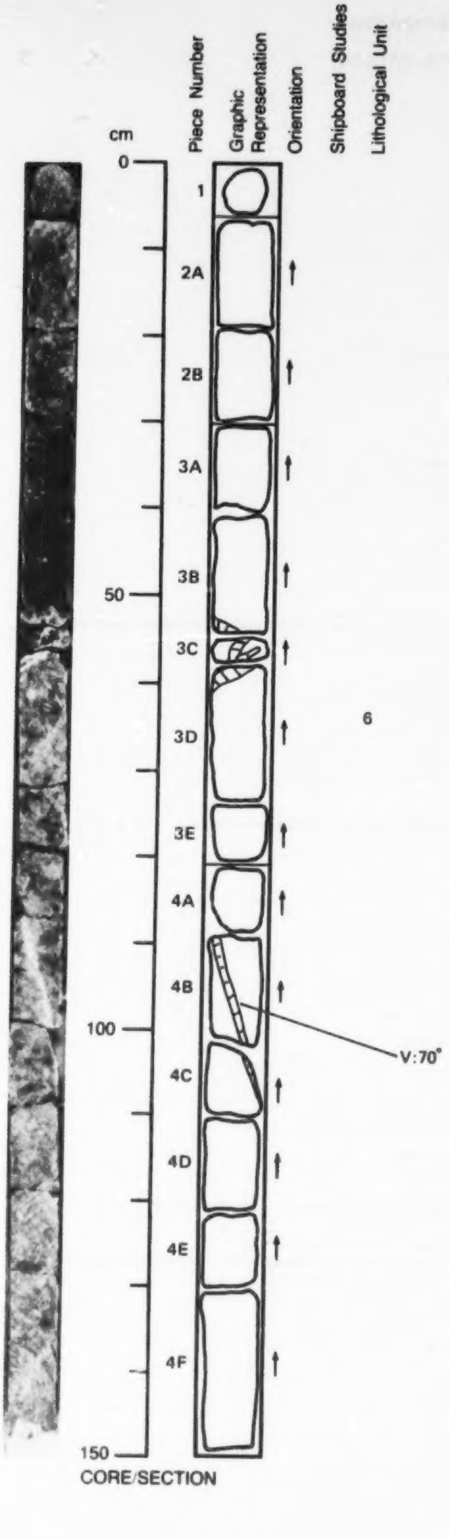
### Olivine Gabbro

### Pieces 5-6

**COLOR:** Dark green.
**LAYERING:** Not seen.
**DEFORMATION:** Thin amphibole vein slightly sheared in Piece 5. Nothing else.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Up to 1.5 cm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: Up to 1.5 cm.
Crystal shape: Not determined.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: 10%-20%.
Crystal size: Up to 1.5 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: >25%
Texture: Amphibole replaces olivine and clinopyroxene. Talc also replaces olivine.
Percent vein material: <1%
Vein material: Amphibole + epidote + sodic plagioclase.
**COMMENTS:** The contact between the troctolite and the olivine gabbro is sharp: it contrasts with the progressive contact observed in Section 118-735B-83R-6.


cm
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V:70°
CORE/SECTION

**118-735B-84R-1**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-4F**

**Olivine Gabbro**

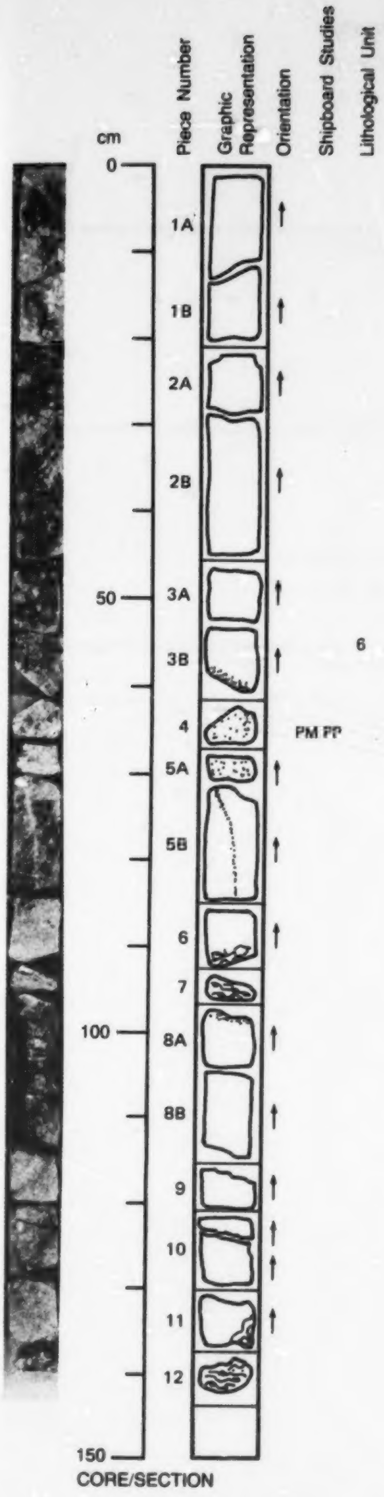
**Pieces 1-4F**

**COLOR:** Gray.
**LAYERING:** Pieces 1, 2, and 3A are slightly more rich in olivine (>5%), grain size is coarse and does not vary significantly.
**DEFORMATION:** None except minute shearing along vein in Piece 4B.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 65%.
Crystal size: 1-4 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%.
Crystal size: 1-4 cm.
Crystal shape: Euhedral-subhedral.
Preferred orientation: None.
Percent replacement: Not determined.

Olivine—Mode: <15%.
Crystal size: 1-4 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 25%.
Texture: Significant replacement of clinopyroxene by green amphibole and replacement aureoles around olivines; this replacement occurs through most pieces due to very thin microfractures filled with green amphibole.
Percent vein material: <1%.
Vein material: Very thin veins filled with amphibole and thicker veins filled with amphibole + sodic plagioclase.

## 118-735B-84R-2



## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-12

### Olivine Gabbro with Porphyroclastic Metagabbro Intervals

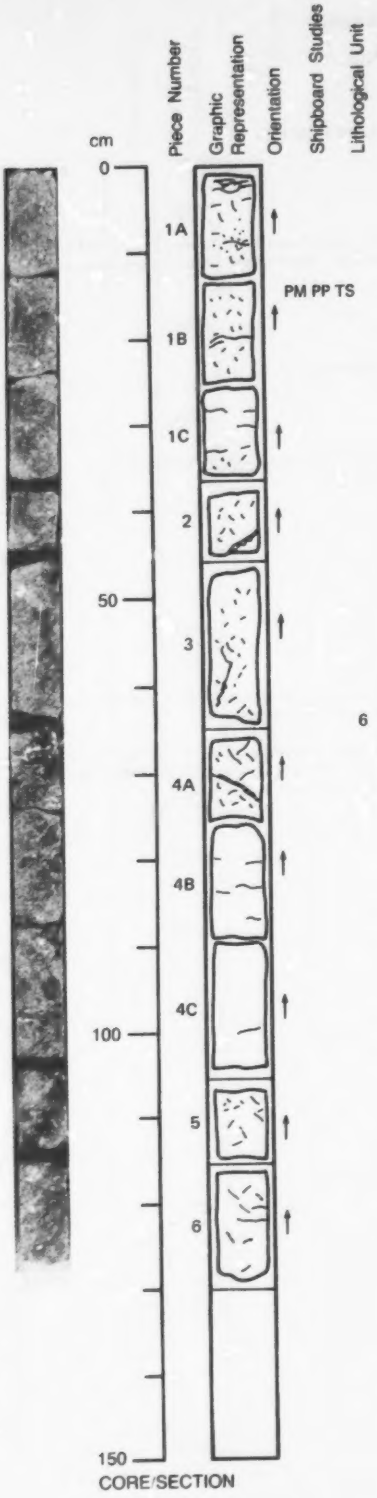
### Pieces 1A-12

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Lower one-half of Pieces 6 and 11, all of Pieces 7 and 12 are porphyroclastic; foliation defined by layers of plagioclase and stretched clinopyroxene. Clinopyroxene forms small augen.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 1-2 cm.
Crystal shape: Anhedral to euhedral
Preferred orientation: Locally in plane of foliation.
Percent replacement: Slight to moderate.

Clinopyroxene—Mode: 40%.
Crystal size: 1-2.5 cm.
Crystal shape: Subhedral. Subophitically encloses plagioclase. It is brown in color.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Slight to moderate.

Olivine—Mode: 10%.
Crystal size: 0.5-1.0 cm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate.

Primary ilmenite—Mode: Trace.
**SECONDARY MINERALOGY:**
Total percent: <1% away from deformed zones.
Texture: Amphibole occurs in very thin veins. Traces of sulfides. In porphyroclastic zones there appears to be an excess of iron oxides in layers parallel to foliation.
Percent vein material: Not determined.
Vein material: Vein in Piece 5B filled by amphibole (actinolite), as are thin veins on the back of Piece 11. Vein/autobrecciation in Pieces 4 and 5A composed of white plagioclase and nearly total replacement of primary clinopyroxene by amphibole.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
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4C
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PM PP TS
6
CORE/SECTION

**118-735B-84R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-6

### Olivine Gabbro

### Pieces 1A-6

**COLOR:** Gray.
**LAYERING:** None clear. Some patchy coarse-fine grain transitions but no clear size or phase layering.
**DEFORMATION:** Minor, 0-3 cm—porphyroclastic gabbro.
**PRIMARY MINERALOGY:**

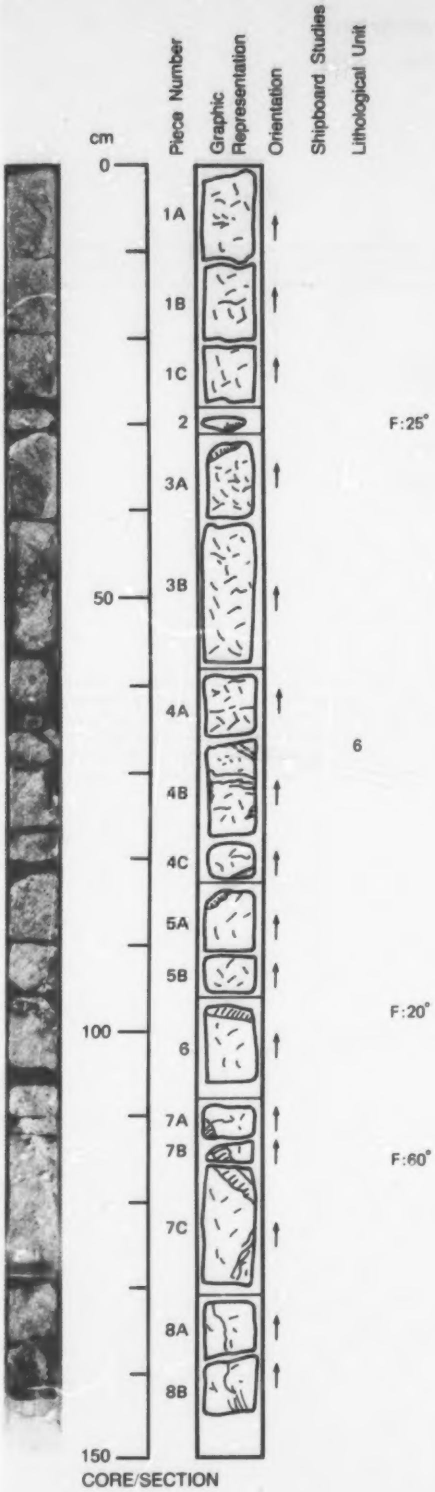
Plagioclase—Mode: 55%-65%.
Crystal size: 1-10 mm.
Crystal shape: Enhedral to anhedral.
Preferred orientation: Not observed.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-35%.
Crystal size: 2-20 mm.
Crystal shape: Anhedral, subophitic to poikilitic, some in delicate flower-like intergrowths with plagioclase.
Preferred orientation: Not observed.
Percent replacement: Not determined.

Olivine—Mode: Not determined.
Crystal size: 2-6 mm.
Crystal shape: Anhedral, partially encloses plagioclase.
Preferred orientation: Not observed.
Percent replacement: In places moderately altered.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Magnetite-tremolite mesh replacing olivine (20%-40%); some amphibolitization of clinopyroxene, particularly around mylonite zone.
Percent vein material: Not determined.
Vein material: 1- to 2-mm-wide amphibole veins at 44, 60, and 72 cm. Numerous, <1-mm, subhorizontal feldspathic veins throughout.



**118-735B-84R-4**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-8B**

**Olivine Gabbro**

**Pieces 1A-8B**

**COLOR:** Gray to white, green-white where veined and altered.

**LAYERING:** Some coarse to fine transitions definable in Pieces 3B (coarse-grained) and 3A (medium-grained), and in Piece 4A (coarse- to medium-grained from bottom to top). Rest of core is medium- to coarse-grained with a fine patch at 7 cm. Veining disrupts some of the size variations.

**DEFORMATION:** Small shear zone associated with veins at 72, 34, and 25 cm. The first has a shallow dip, the second dips steeply—may be a surface inclined at a shallow angle to the cut surface.

**PRIMARY MINERALOGY:**

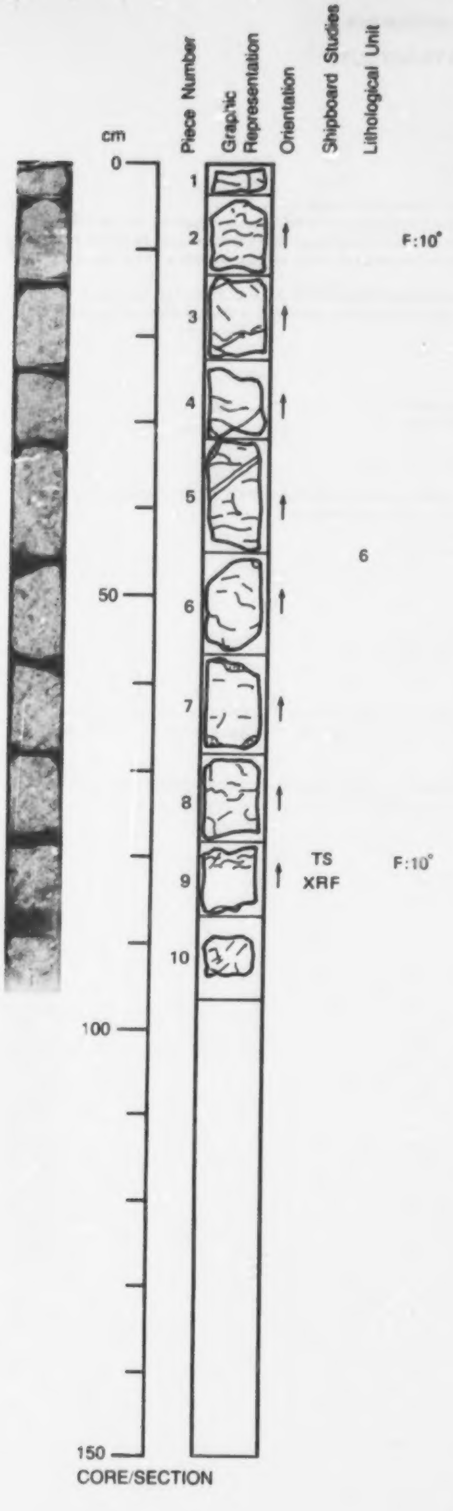
Plagioclase—Mode: 50%-70%.
Crystal size: 2-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 3-7 mm.
Crystal shape: Subhedral in coarser portions, anhedral, ophitic in finer portions, 3-7-mm clinopyroxene, have a brownish hue on cored surface.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.

**SECONDARY MINERALOGY:**

Total percent: 10%.
Texture: Mesh alteration of olivine. Amphibolization of clinopyroxene intense along veins. No quartz obvious. Often some shear along the margins and extensive alteration of the adjacent pyroxene.
Percent vein material 8%.
Vein material: 4- to 10-mm-wide veins of plagioclase + actinolite + brown epidote. Numerous subhorizontal fractures, some with feldspathic veins (< 1 mm wide).



### 118-735B-84R-5

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-10**

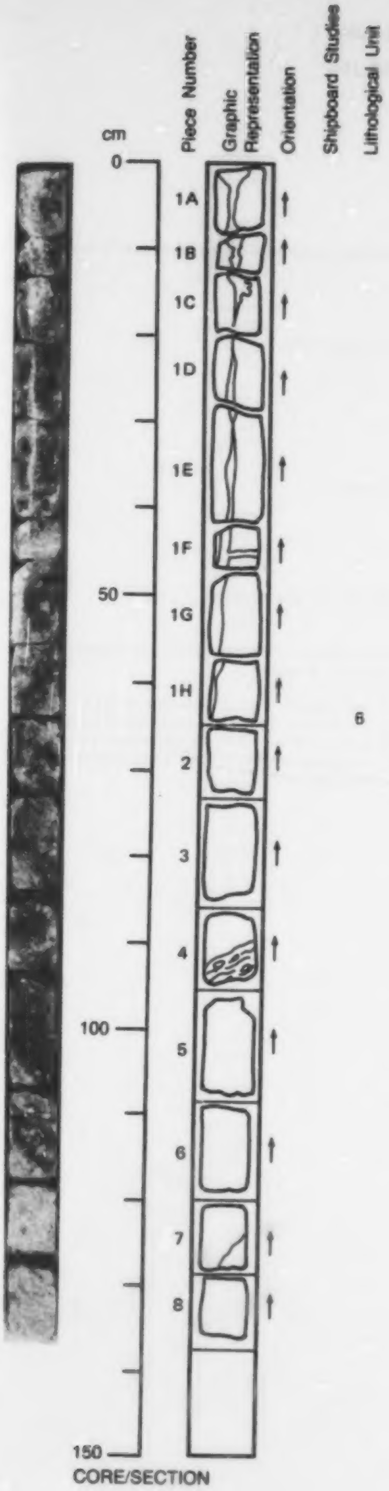
**Olivine Gabbro**

**Pieces 1-10**

**COLOR:** Greenish gray.
**LAYERING:** Not present.
**DEFORMATION:** Visible in Pieces 2 and 9. The foliation is defined by the stretching and preferred orientation of plagioclase and clinopyroxene. In Piece 2 the deformation affects all pieces and pyroxenes are more intensively amphibolitized. Massive magnetite and ilmenite zone present in interstitial spaces.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-3 mm.
Crystal shape: Euhedral (chadacrysts).
Preferred orientation: Weak.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-12 mm.
Crystal shape: Oikocrystic to anhedral.
Preferred orientation: Weak.
Percent replacement: Slight.

Olivine—Mode: 5%-10%.
Crystal size: 1-5 mm.
Crystal shape: Irregular, anhedral.
Preferred orientation: Not visible.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: >25%.
Textures: Olivine is altered to dark talc and magnetite with some proportions of brown clays. Plagioclase is replaced by milky sodic plagioclase (in Pieces 1, 2, 3, and 10). This plagioclase is cut by green amphibole veinlets. Clinopyroxene is altered to amphibole close to veins and cracks. Piece 2 is injected by secondary magnetite and sulfides along the plane of foliation. The oxides content reaches 20%. The sulfides are mainly chalcopyrite, pyrite, and pentlandite. Ilmenite-magnetite intergrowth is present in Piece 7 but could be primary.
Percent vein material: 2%.
Vein material: Green amphibole.



**118-735B-84R-6**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-8

### Olivine Gabbro

### Pieces 1A-8

**COLOR:** Gray.
**LAYERING:** Size-grading and phase-layering present. Grain size coarsens downsection from 0-92 cm from an average plagioclase lath size of 1 to 1.5 cm. Plagioclase-rich layer present in Piece 1D (26-28 cm) where it composes 80% of a 3 cm interval.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-75%.
Crystal size: Averages 1-1.5 cm.
Crystal shape: Euhedral to subhedral laths.
Preferred orientation: None.
Percent replacement: <10%.

Clinopyroxene—Mode: 15%-35%.
Crystal size: 3-20 mm.
Crystal shape: Subophitic to intergranular anhedral.
Preferred orientation: None.
Percent replacement: <10%.

Olivine—Mode: 5%-20%.
Crystal size: Not determined.
Crystal shape: Intergranular anhedral.
Preferred orientation: None.
Percent replacement: <10%.

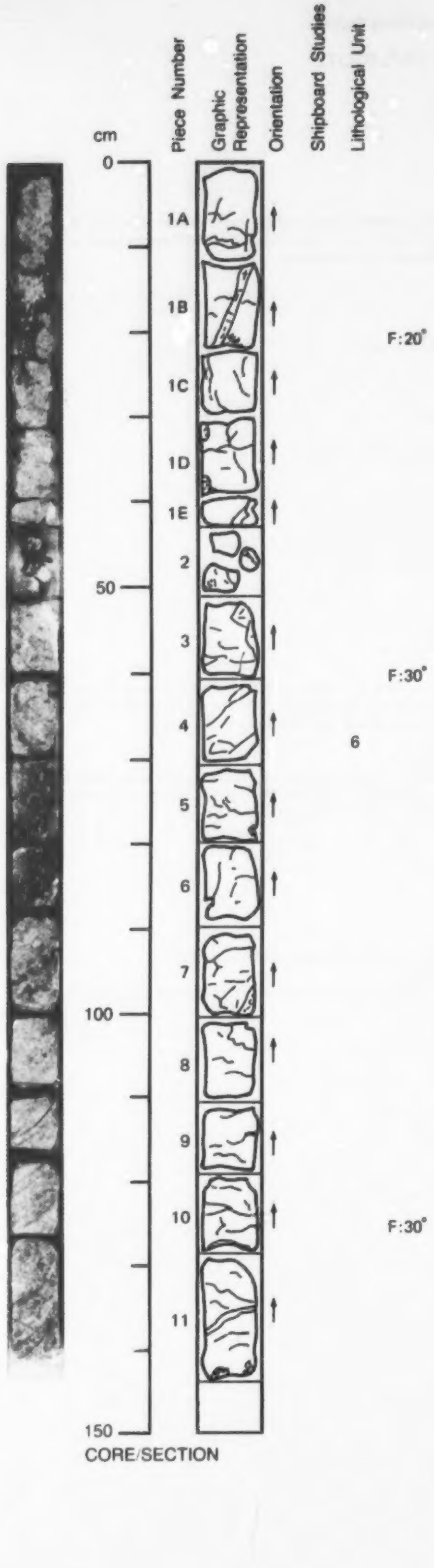
Oxides and Sulfides—Mode: <1%.

**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: A large felsic vein tapering from 3 to 1 cm wide downsection through Pieces 1A-1H contains secondary salite (clinopyroxene) and has a plagioclase with a milky white color. Altered plagioclase in the gabbro adjacent to the vein also is milky white.
Percent vein material: 5%.
Vein material: Plagioclase and diopside.
**COMMENTS:** Equigranular gray subophitic to intergranular olivine gabbro. Euhedral to subhedral plagioclase partially enclosed by subophitic pyroxene and intergranular green olivine. Pyroxene is probably augite, but has a peculiar reddish brown cast to it.

### Porphyroclastic Augen Gneiss

### Piece 4 (90-95 cm)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Poorly foliated augen gneiss, deformed zone of olivine gabbro.
**PRIMARY MINERALOGY:** As in olivine gabbro.
**SECONDARY MINERALOGY:** As in olivine gabbro but with additional replacement and rimming of clinopyroxene by amphibole.
**COMMENTS:** Local enrichment of oxides.



## 118-735B-84R-7

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-11**

### Massive to Slightly Foliated Olivine Gabbro

**Pieces 1A-11**

**COLOR:** Gray to brownish gray.

**LAYERING:** Not present.

**DEFORMATION:** Preferred orientation of plagioclase and pyroxene in Pieces 1C, 4, and 11. This foliation is probably magmatic.

**PRIMARY MINERALOGY:**

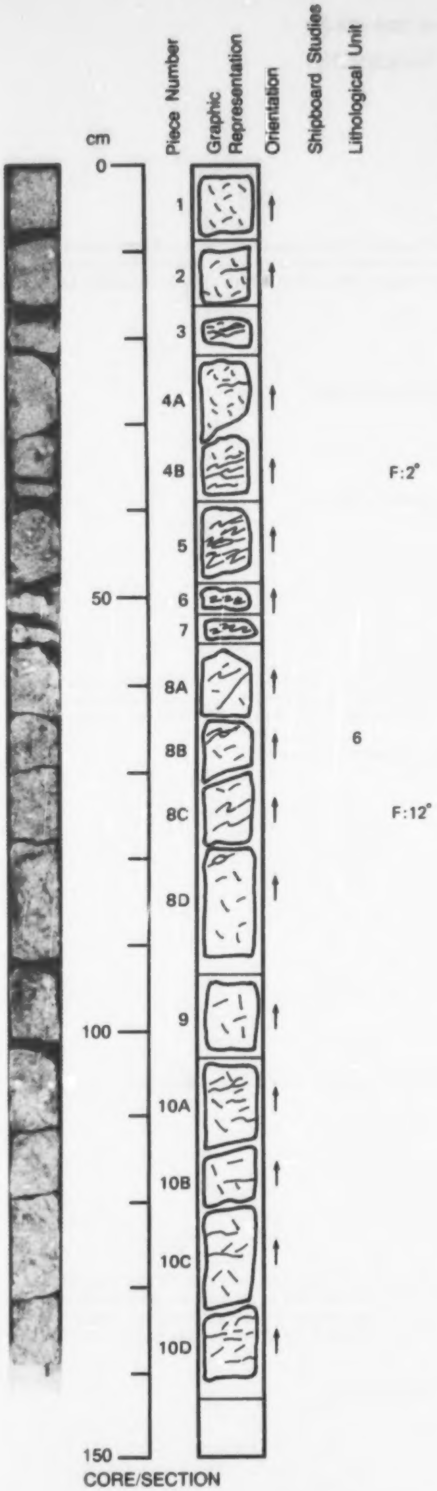
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Euhedral (chadacrysts in clinopyroxene).
Preferred orientation: Not visible.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 2-15 mm.
Crystal shape: Oikocrysts.
Preferred orientation: Variable.
Percent replacement: 30% by brown amphibole.

Olivine—Mode: 5%-15%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: Not visible.
Percent replacement: 20% by clays or chlorite, talc and magnetite.

**SECONDARY MINERALOGY:**

Total percent: 5%-10%.
Texture: Olivine is replaced by dark clays or chlorite and rimmed by talc and magnetite.
Clinopyroxene is partly replaced (30%) by brown amphibole.
Percent vein material: 3%-4%.
Vein material: Veins are filled with plagioclase, epidote, and actinolite (Pieces 1E, 7, and 8). Clinopyroxene is slightly amphibolitized near the vein. Other types of vein are filled by grass-green amphibole (dipping 70°). Clinopyroxene is amphibolitized and plagioclase is albitized in less than 1 cm away from the vein walls. In flat, dipping cracks, there are amphibole and chlorite. Sulfides are disseminated throughout the section.



## 118-735B-85R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-10D

### Olivine Gabbro

### Pieces 1-10D

**COLOR:** Gray to green-gray, and white where altered.

**LAYERING:** None well-defined. Deformation obscures grain size changes. A medium- to coarse-grained interval at 14-0 cm; 20-30 cm is medium- to coarse-grained; 80-140 cm is uniformly coarse-grained. Some lamination may be igneous.

**DEFORMATION:** Porphyroclastic gabbro from 35 to 80 cm, also a small deformation zone at 20 cm. Texture is interspersed porhyroclastic zones (clasts up to 10 mm) with less-deformed, igneous-textured pieces; the latter are probably blocks within the deformed zone. Lower boundary of zone is marked by a 7-mm-wide, oxide-rich zone.

**PRIMARY MINERALOGY:**

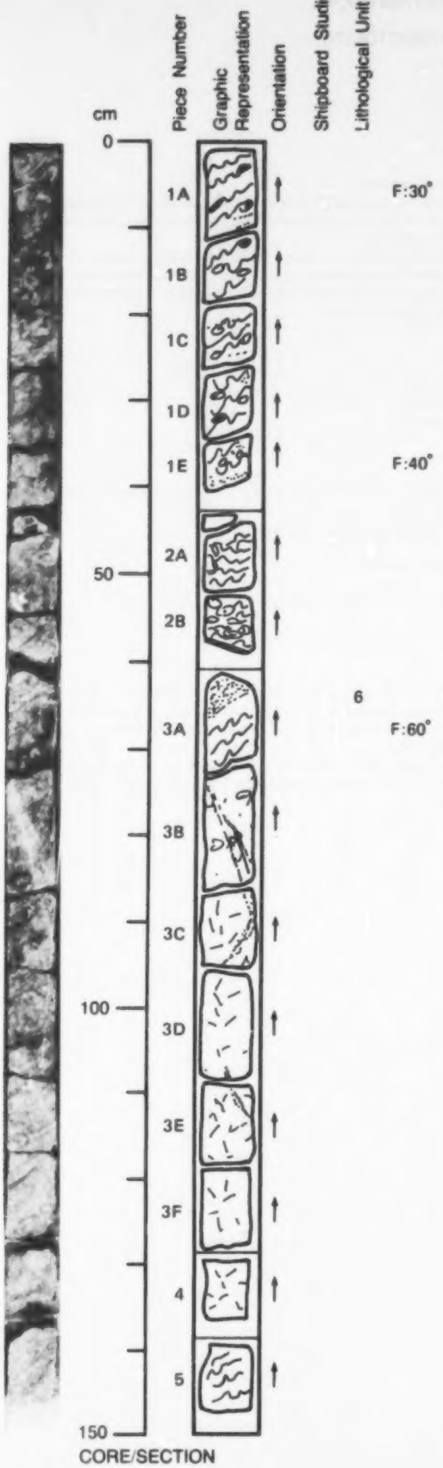
Plagioclase—Mode: 45%-65%.
Crystal size: 4-12 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None observed.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-45%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral to anhedral, granular to ophitic. Clinopyroxenes are brownish.
Preferred orientation: None observed.
Percent replacement: 30%-80% amphibolitization in shear zones.

Olivine—Mode: 5%-20% in coarser sections.
Crystal size: 3-13 mm.
Crystal shape: Anhedral to subhedral, sometimes enclosing plagioclase.
Preferred orientation: None observed.
Percent replacement: Extensively altered in deformed zone.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine and clinopyroxene commonly altered, particularly in deformation zone. Olivine altered to dark magnetite/amphibole pseudomorphs, also to dark clayey aggregates in more deformed zones. 30%-80% amphibolitization of clinopyroxene in sheared zones.
Percent vein material: Not determined.
Vein material: Minor late stage epidote veins cutting foliation (Piece 8A). Thin, streaky, white, subhorizontal veins common (Piece 10C). Some subhorizontal brittle fractures throughout.



**118-735B-85R-2**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-5

### Porphyroclastic Augen Gneiss

### Pieces 1A-3A, and 5

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic texture. Foliation defined by layers of plagioclase and stretched porphyroclasts of clinopyroxene. Over most of the section deformation is not too intense and consists mostly of granulation of feldspar. Areas of apparently undeformed gabbro are mixed in with areas of deformation.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Extensive.

Clinopyroxene—Mode: 45%.
Crystal size: 8-15 mm.
Crystal shape: Subhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Extensive.

Olivine—Mode: 5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: Approximately 75%.
Texture: Plagioclase recrystallized to neoblasts. Actinolite replaces clinopyroxene along grain boundaries and plagioclase adjacent to fractures. Abundant iron oxides and traces of sulfides in Pieces 1A-E. These are much less abundant in top of Piece 2A and absent below.
Percent vein material: ~5%.
Vein material: Amphibole on thin fractures.

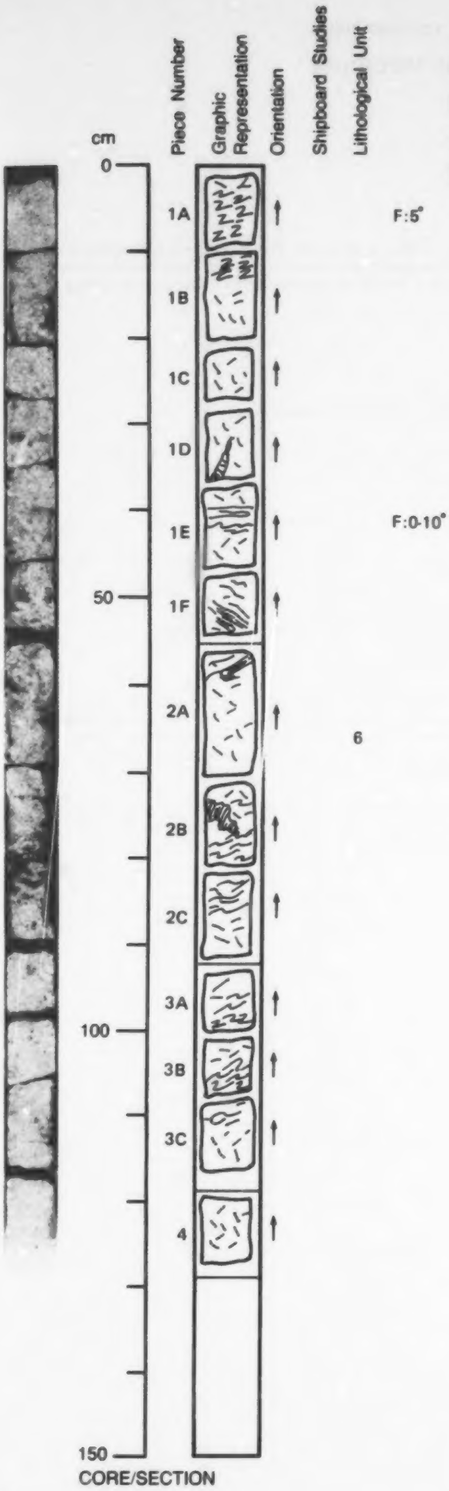
### Olivine Gabbro

### Pieces 3B-F, and 4

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Very slight.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%.
Crystal size: 5-10 mm.
Crystal shape: Subhedral.
Preferred orientation: None.
Percent replacement: 2%-5%.

Clinopyroxene—Mode: 45%.
Crystal size: 8-15 mm.
Crystal shape: Subhedral. Clinopyroxene subophitically encloses plagioclase.
Preferred orientation: None.
Percent replacement: 2%-5%.

Olivine—Mode: 5%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 30%.
**SECONDARY MINERALOGY:**
Total percent: Slight.
Texture: Plagioclase is milky white in Pieces 2A, top of 2B, bottom of 2C, and top of 3A, also adjacent to vein that crosscuts Pieces 3B and 3C. May be intense granulation or albitization. These veins have pale green centers that are probably a fine-grained mixture of plagioclase and actinolite. This green material is also found at the bottom of Piece 2C and top of Piece 3A.
Percent vein material: <1%.
Vein material: Sodic plagioclase and actinolite.



## 118-735B-85R-3

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-4

### Olivine Gabbro to Porphyroclastic Olivine Gabbro

### Pieces 1A-4

**COLOR:** Gray to green-gray and white.

**LAYERING:** Some size gradations, although deformation has obscured most of the changes. Coarse to very coarse layers at 50-55, 81-85, and 110-111 cm. These are often somewhat sheared and elongate.

**DEFORMATION:** Porpyhroclastic zones common throughout core: 5-12, 40-45, 78-85, and 95-105 cm. Commonly some evidence of brecciation or deformation in the intervening gabbroic sections. Zones of oxide commonly associated with deformation zones or their margins.

**PRIMARY MINERALOGY:**

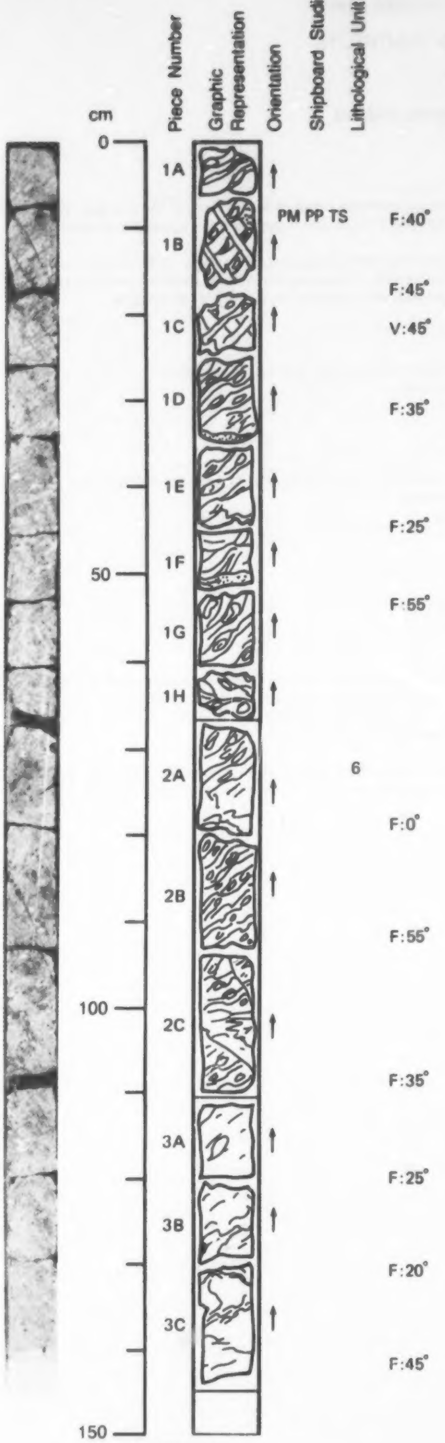
Plagioclase—Mode: 40%-50%.
Crystal size: 3-8 mm.
Crystal shape: Euhedral, subhedral, enclosed partially by clinopyroxene.
Preferred orientation: None observed.
Percent replacement: 10%-20%.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 3-30 mm.
Crystal shape: Largest grains subhedral, smaller subhedral to anhedral and ophitic.
Preferred orientation: None observed.
Percent replacement: 10%-50%.

Olivine—Mode: 5%-10%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: None observed.
Percent replacement: 10%-50%.

**SECONDARY MINERALOGY:**

Total percent: Up to 30%.
Texture: Olivine altered to dark magnetite-tremolite-talc; completely altered to dark clayey pseudomorphs in deformed zones. Clinopyroxene variously amphibolitized, particularly in deformated zones. Secondary oxides up to 20% or 30% in margins of shear zones. Minor sulfide. Freshest pieces are Pieces 2A, 3C, and 4.
Percent vein material: 5%.
Vein material: Two veins (3 and 10 mm) of actinolite + epid [illegible] plagioclase at 35 and 75 cm. Amphibole-rich veins at 88 cm. Thin, streaky, white, subh [illegible] veins throughout.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
CORE/SECTION
1A
1B
1C
1D
1E
1F
1G
1H
2A
2B
2C
3A
3B
3C
PM PP TS
6
F:40°
F:45°
V:45°
F:35°
F:25°
F:55°
F:0°
F:55°
F:35°
F:25°
F:20°
F:45°

**118-735B-85R-4**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-3C**

**Porphyroclastic Olivine Gabbro**

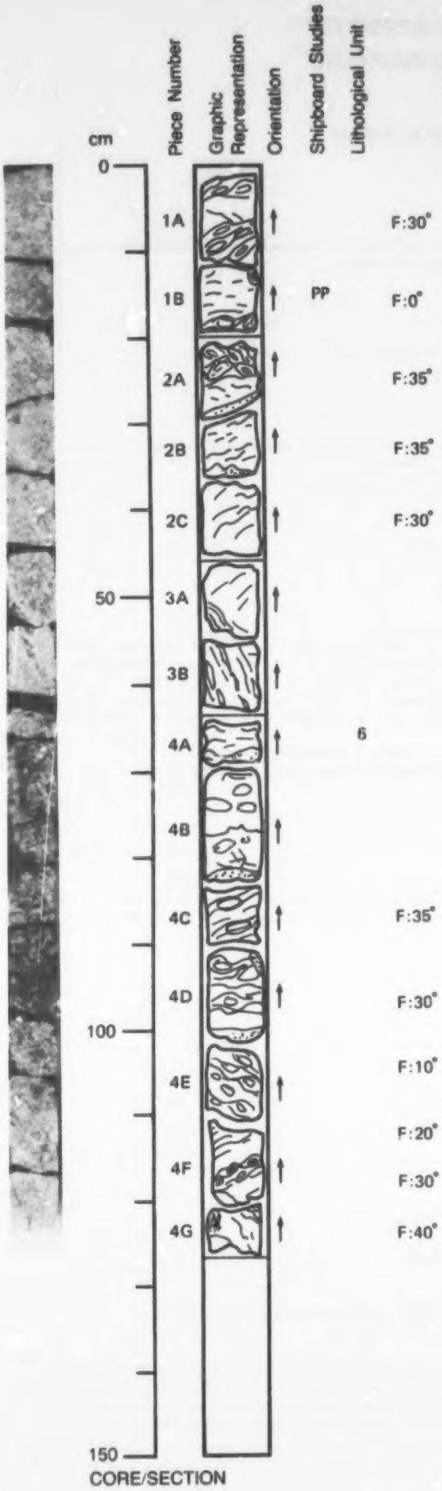
**Pieces 1A-3C**

**COLOR:** Grayish green.
**LAYERING:** Not apparent.
**DEFORMATION:** Yes, all sections. The foliation is developed when plagioclase is stretched and granulated and clinopyroxene elongated into the foliation plane. There is a discontinous plagioclase banding, developed in Pieces 1B, 1E, and 1F. The foliation is cut at right angles by green amphibole.
**PRIMARY MINERALOGY:**
Plagioclase— Mode: 55%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: Strong.
Percent replacement: Slightly altered to sodic plagioclase.

Clinopyroxene— Mode: 40%.
Crystal size: 1-15 mm.
Crystal shape: Elongated, lensoid.
Preferred orientation: Strong.
Percent replacement: 90% by green and brown amphibole.

Olivine—Mode: 5%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral.
Preferred orientation: Not seen.
Percent replacement: Slightly altered to chlorite, magnetite, and clays.

**SECONDARY MINERALOGY:**
Total percent: 30%-100%.
Texture: Olivine is replaced by black chlorite and magnetite with brown clays. Clinopyroxene is largely (90%?) replaced by green amphibole, brown amphibole, and dark rims (blue-green amphibole type). The replacement is total near late stage veins. Plagioclase is deformed and recrystallized into neoblasts and transposed into the foliation plane. It is probably transformed into sodic plagioclase.
Percent vein material: 6%.
Vein material: Veins are filled with dark amphibole on the walls and lighter green actinolite and plagioclase in the center. Secondary magnetite and ilmenite are abundant in Pieces 1E and 1F. Disseminated sulfides are present.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
0
50
100
150
1A
1B
2A
2B
2C
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3B
4A
4B
4C
4D
4E
4F
4G
PP
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F:0°
F:35°
F:35°
F:30°
F:35°
F:30°
F:10°
F:20°
F:30°
F:40°
CORE/SECTION

### 118-735B-85R-5

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-4G

### Porphyroclastic Olivine and Oxide-Bearing Gabbros

### Pieces 1A-4G

**COLOR:** Grayish green.

**LAYERING:** Not present.

**DEFORMATION:** All samples are foliated showing clinopyroxene porphyroclasts up to 2 cm thick surrounded by neoblastic plagioclase. The foliation is deflected by the porphyroclasts. Olivine is also elongated into lenses.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 50%-65%.
Crystal size: 1-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Variable, moderate.
Percent replacement: 10% by sodic plagioclase.

Clinopyroxene— Mode: 40%-45%.
Crystal size: 3-20 mm.
Crystal shape: Anhedral. Fresh clinopyroxene is pinkish brown.
Preferred orientation: Variable, moderate.
Percent replacement: 40%-100% by amphibole.

Olivine—Mode: 2%-5%.
Crystal size: 1-5 mm.
Crystal shape: Elongated, lenses.
Preferred orientation: None.
Percent replacement: Slightly altered to clays and talc.

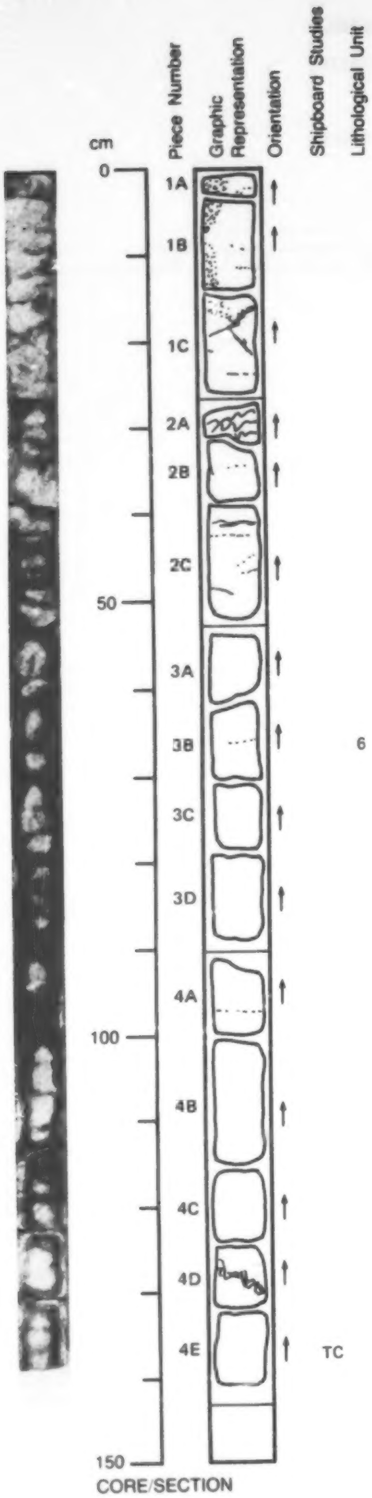
**SECONDARY MINERALOGY:**

Total percent: <20%.

Texture Ilmenite and magnetite invade the pore spaces of largely amphibolitized gabbros. Chalcopyrite and pyrite are widespread in the interstices (Pieces 4B to 4G). Clinopyroxene is replaced by green and light green amphibole, especially near late-stage veins and ilmenite-rich zones. Olivine is replaced by clays in the center and surrounded by talc. Plagioclase is replaced by milky sodic plagioclase in same shear zones.

Percent vein material: 3%.

Vein material: Veins filled with green amphibole, plagioclase, and oxides.



**118-735B-85R-6**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-4E

### Olivine Gabbro to Porphyroclastic Olivine Gabbro

### Pieces 1A-2C (top)

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Some foliation apparent in Piece 2A. Foliation defined by recrystallized plagioclase and stretched augen of pyroxene and olivine.
**PRIMARY MINERALOGY:**
Plagioclase— Mode: 45%.
Crystal size: 8-12 mm.
Crystal shape: Subhedral.
Preferred orientation: In plane of foliaation.
Percent replacement: Moderate.

Clinopyroxene—Mode: 45%.
Crystal size: 10-20 mm.
Crystal shape: Subhedral; clinopyroxene brown and poikilitically encloses plagioclase.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate.

Olivine—Mode: 10%.
Crystal size: 3-7 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: Approximately 30%-40%.
Texture: Discontinous vein through Pieces 1A-C composed of sodic plagioclase, some actinolite, and epidote. Adjacent plagioclase in gabbro appears to be more sodic as well. Actinolite along numerous thin fractures having a nearly vertical orientation. Thin, nearly horizontal white veins, probably plagioclase. Olivine altered in meshlike fashion by black metallic mineral. Traces of sulfides. Piece 2C contains a contact between olivine gabbro and fine-grained troctolite.
Vein material: Sodic plagioclase, actinolite, and epidote.
**COMMENTS:** Contact with underlying troctolitic diabase in Piece 2C, approximately 41 cm.

### Troctolite

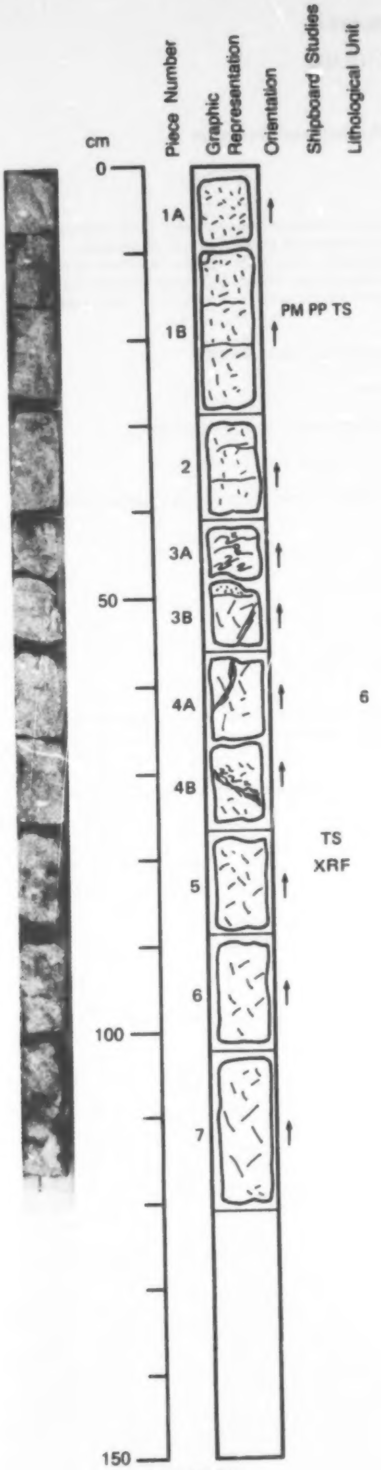
### Pieces 2C (bottom)-4E

**COLOR:** Gray.
**LAYERING:** Possible primary layering defined in Piece 4D, where a 1-cm-wide olivine layer is enclosed poikilitically by a single clinopyroxene. Orientation of this layer approximately 45°.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal shape: Anhedral.
Crystal size: Variable (0.5 mm to 1 cm).
Prefereed orientation: None.
Percent alteration: Slight to moderate.

Clinopyroxene—Mode: <5%.
Crystal shape: Skeletal oikocrysts.
Crystal size: Variable (0.5 mm to 1 cm).
Preferred orientation: None.
Percent alteration: Moderate.

Olivine—Mode: 35%-50%.
Crystal shape: Anhedral.
Crystal size: Variable (0.5 mm to 1 cm).
Preferred orientation: None.
Percent alteration: Slight to moderate.
**SECONDARY MINERALOGY:**
Total percent: 30%-40%.
Texture: Abundant amphibole filling thin, nearly vertical fractures/veins.
Percent vein material: <1%.
Vein material: Amphibole.
**COMMENTS:** Granular texture. Grain size slightly more variable in Section 118-735B-85R-6 than in Section 118-735B-85R-7. Grain sizes are less than 0.5 mm in diabase zones, but up to 1 cm in coarser-grained areas. Note that grain size decreases gradually from troctolitic gabbro at 52 cm to troctolitic diabase at 141 cm. Diabase also occurs between 41 and 52 cm.

## 118-735B-85R-7



## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-7

### Troctolite

### Pieces 1A-2

**COLOR:** Light gray.
**LAYERING:** None.
**DEFORMATION:** Lower contact with a porphyroclastic zone.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None observed.
Percent replacement: Not determined.

Clinopyroxene—Mode: <5%.
Crystal size: 1-2 mm.
Crystal shape: Skeletal oikocrysts.
Preferred orientation: None observed.
Percent replacement: Not determined.

Olivine—Mode: 35%-50%.
Crystal size: 1-2 mm.
Crystal shape: Anhedral.
Preferred orientation: None observed.
Percent replacement: Slightly altered.
**SECONDARY MINERALOGY:**
Total percent: 30%-75%.
Texture: Not determined.
Percent vein material: 1%.
Vein Material: A few streaky, subhorizontal white veins <1 mm wide.

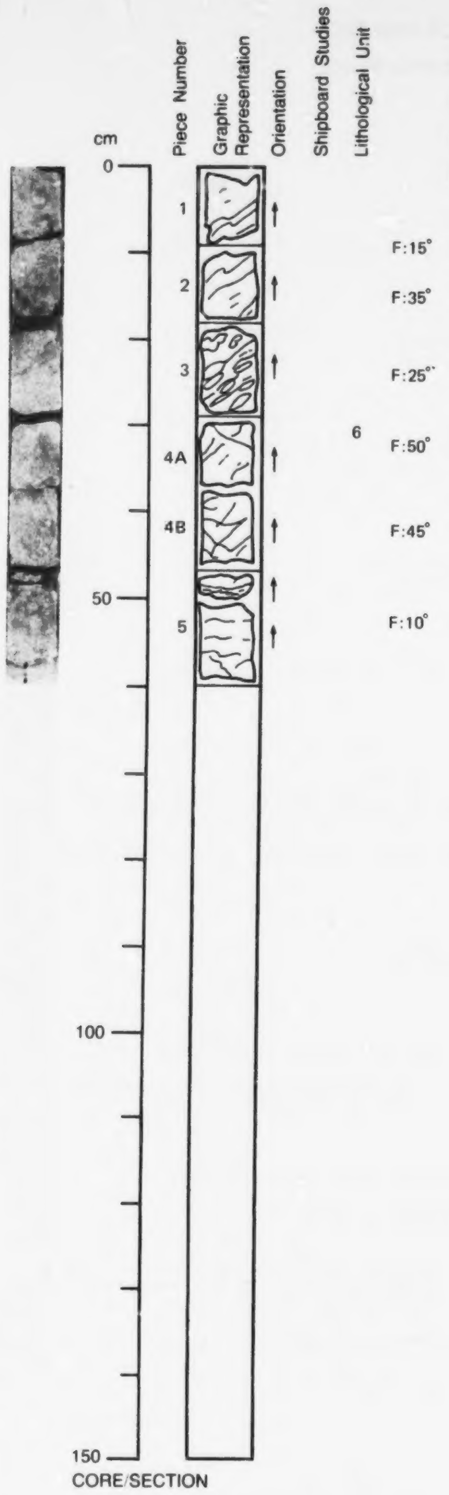
### Olivine Gabbro

### Pieces 3A-7

**COLOR:** Gray to gray-green and white where altered.
**LAYERING:** Nice, coarse- to fine-sized variations. A very coarse (2 cm) layer at 58 cm, with a sharp contact having a fine-grained section at 50 cm. A very coarse through medium to medium-fine section at 120-70 cm.
**DEFORMATION:** Porphyroclastic gabbro at 42-48 cm at transition of troctolite to olivine gabbro. A little shear along vein in Piece 4B.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%-50%.
Crystal size: 2-40 mm.
Crystal shape: Anhedral, subhedral.
Preferred orientation: None observed.
Percent replacement: 30%.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 3-30 mm.
Crystal shape: Subhedral in coarse sections to large oikocrysts in finer sections.
Perferred orientation: None.
Percent replacement: On cored surface they are brown and dull emerald-green. In some cores, the green appears to be replacing the brown clinopyroxene.

Olivine—Mode: Up to 10%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral to subhedral, partially enclosing plagioclase.
Preferred orientation: None.
Percent replacement: Partial alteration common.
**SECONDARY MINERALOGY:**
Total percent: 30%.
Texture: Large (2-3 mm) actinolite-plagioclase vein cutting Pieces 3B and 4A; smaller amphibole vein in Piece 4B. Extensive amphibolitization of clinopyroxene in deformation zone. Olivine usually partly altered to dark meshlike structure.
Percent vein material: 2%.
Vein material: Actinolite, plagioclase, and amphibole.



118-735B-85R-8

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-5**

### Porphyroclastic to Slightly Foliated Olivine Gabbro and Troctolite

**Pieces 1-5**

**COLOR:** Gray to greenish gray.

**LAYERING:** Modal layering; Piece 2 is impoverished in clinopyroxene oikocrysts, while other pieces show various amounts of clinopyroxene. Contacts are transposed into the foliation.

**DEFORMATION:** Present in all samples, less important in Piece 2. The foliation is defined by preferred orientation of plagioclase. In Pieces 4A and 4B, this foliation is probably primary. Grain size is reduced to 1 mm or less when compared to 2-3 mm average of undeformed part of the samples.

**PRIMARY MINERALOGY:**

Plagioclase—Mode: 65% (in Piece 2); 10%-15% (in other pieces).
Crystal size: 1-10 mm.
Crystal shape: Euhedral when chadocrysts.
Preferred orientation: Weak.
Percent replacement: Slightly altered in shear zones to sodic plagioclase.

Clinopyroxene—Mode: 5% (in Piece 2); 30%-40% (in other pieces).
Crystal size: Up to 3 cm.
Crystal shape: Oikocrystic to anhedral. Oikocrysts have subophitic plagioclase inclusions.
Fresh clinopyroxene is pinkish brown.
Preferred orientation: Weak.
Percent replacement: 40% by amphibole.

Olivine—30% (in Piece 2); 10%-15% (in other pieces).
Crystal size: 1-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: 20% by talc, magnetite, and tremolite.

**SECONDARY MINERALOGY:**

Total percent: Not determined.
Texture: Olivine is replaced by talc and magnetite and tremolite fibers. Clinopyroxene (pinkish brown when fresh) is replaced by grass-green amphibole. Plagioclase is milky sodic plagioclase in the shear zones.
Percent vein material: 5%.
Vein Materials: Veins (in the plane of foliation) or cutting the foliation at right angle are filled with amphibole and plagioclase.

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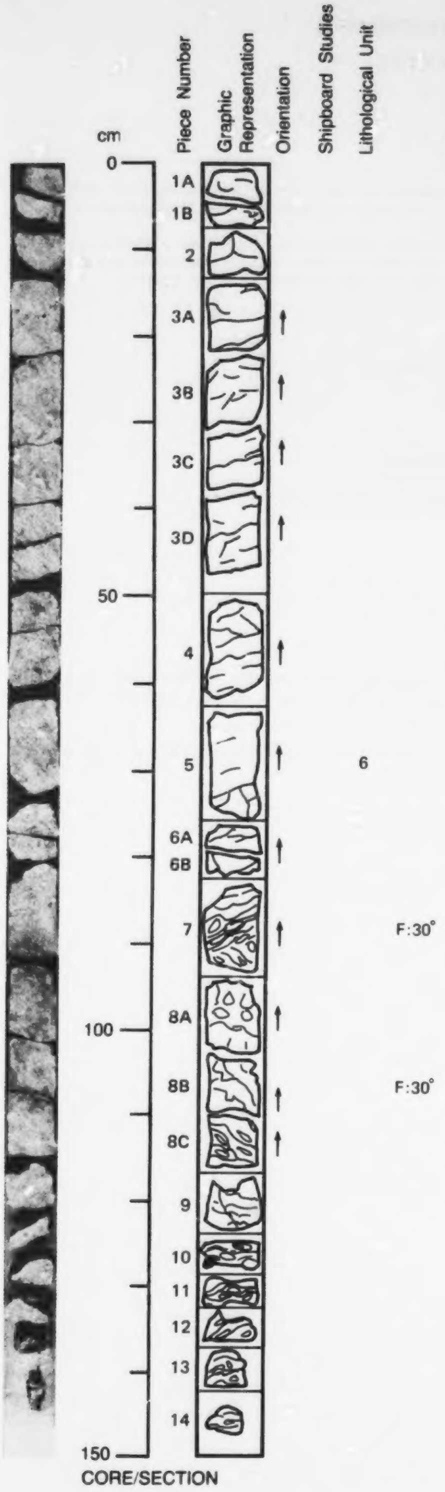


## 118-735B-86R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-14

### Massive Gabbro (Pieces 1A-5), Porphyroclastic Gabbro (Pieces 5-12, and 14), and Augen Gneissic Gabbro (Piece 13)

**COLOR:** Greenish gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Foliation is visible from base of Pieces 5 to 14. Elongated clinopyroxene porphyroclasts and discontinuous bands of neoblastic plagioclase define foliation planes. In Piece 14, the plagioclase and pyroxene (now amphibole) are regular. Augen of 1-2 mm in diameter are present. Grain-size reduction is from 1 cm (average) to 3-5 mm, with deformation increasing (>2 mm in gneissic gabbro).
**PRIMARY MINERALOGY:**

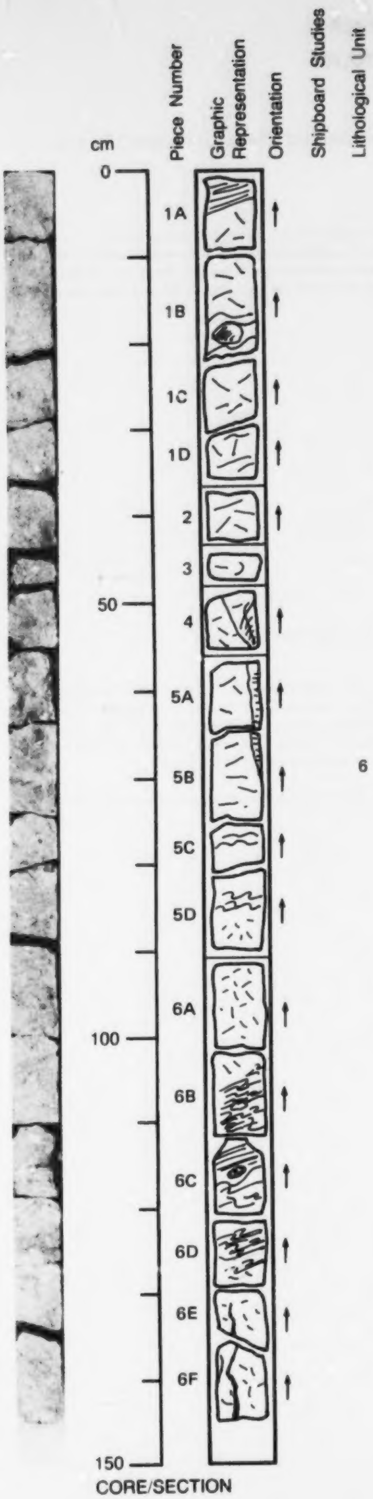
Plagioclase—Mode: 50%-60%.
Crystal size: 1-4 mm.
Crystal shape: Euhedral to anhedral.
Preferred orientation: None.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-15 mm.
Crystal shape: Oikocrystic, anhedral.
Preferred orientation: Weak.
Percent replacement: Severely altered to amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 1-6 mm.
Crystal shape: Anhedral, rounded.
Preferred orientation: None observed.
Percent replacement: Slightly altered to talc, magnetite, and clays.

**SECONDARY MINERALOGY:**

Total percent: 10%-30%.
Texture: Olivine is partly replaced by talc and magnetite and by brown clays. Clinopyroxene is almost totally replaced by green amphibole in deformed gabbro, but only slightly in massive gabbros (20%). Plagioclase is slightly albitized in Pieces 1B, 2, 6A, 6B, 7, 12, and 14 Abundant magnetite, ilmenite, and sulfides are present in Pieces 7, 8A, 8B, 8C, and 9. Sulfides are mainly chalcopyrite, which are interstitial or infiltrated in silicate grains.
Percent vein material: <1%.
Vein material: Subhorizontal fractures are filled with calcite, actinolite, talc, and chlorite.



118-735B-86R-2

## UNIT 6: OLIVINE GABBRO AND TROCOLITE

### Pieces 1A-6F

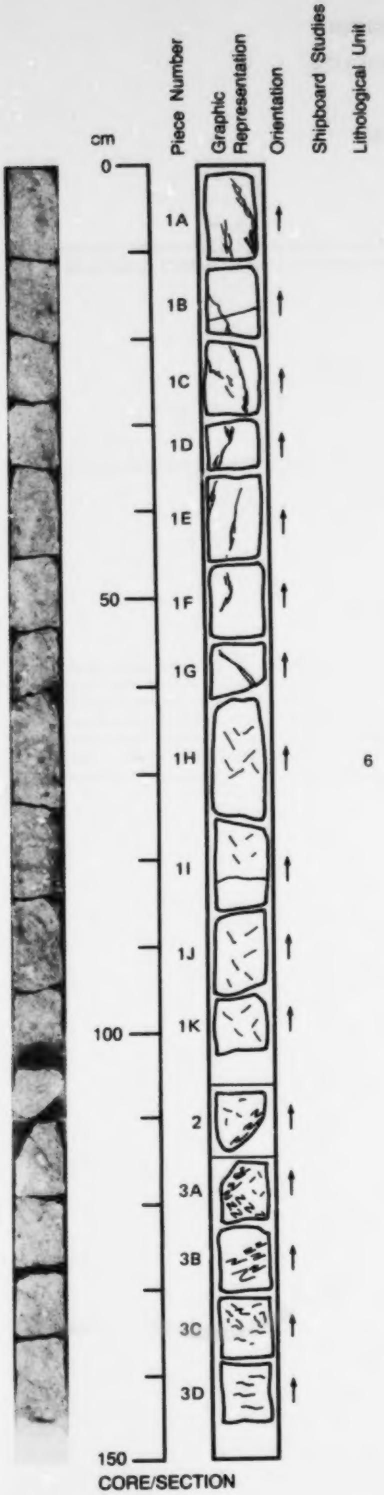
### Mylonitic to Porphyroclastic Gabbro

**COLOR:** Gray-green to gray-white.
**LAYERING:** Obscured by deformation. Upper part of core is very coarse-grained (to 3 cm; 0-75 cm), lower part (85-145 cm) is medium-grained, where igneous textures are discernable. Oxide-rich zones at 24-26 cm and 125-127 cm.
**DEFORMATION:** Mylonitic zones at 0-5 and 105-120 cm; porphyroclastic zones at 15-20, 35, 75-85, 120-130 cm, interspersed with less deformed gabbro. Also some brecciation and elongation in those sections. Pieces 6E and 6F are little deformed medium-grained gabbro.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 2-12 mm.
Crystal shape: Subhedral.
Preferred orientation: Aligned in foliation.
Percent replacement: 10-40%.

Clinopyroxene—Mode: 35%-60%.
Crystal size: 2-30 mm.
Crystal shape: Anhedral to subrounded.
Preferred orientation: Aligned infoliation.
Percent replacement: Extensively amphibolitized in deformation zones.

Olivine—Mode: 5%.
Crystal size: 2-8 mm.
Crystal shape: Anhedral.
Preferred orientation: Not determined.
Percent replacement: Very altered.

**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Olivine to clay, magnetite, tremolite, particularly dark pseudomorphs along shear zones. Clinopyroxene extensively amphibolitized in deformed zones. Deformation is pervasive in the section, except for the bottom two pieces.
Percent vein material: 5%.
Vein material: 1-2 mm amphibole vein in Pieces 6E, 6F. Feldspar, epidote, and actinolite vein fill on side of Piece 5A.



**118-735B-86R-3**

### UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-3D**

**Amphibolitized Olivine Gabbro**

**Pieces 1A-3D**

**COLOR:** Green-gray to green and white where veined.

**LAYERING:** None apparent. Most of core is medium- to coarse-grained. One very coarse-grained layer at 65-70 cm, dipping into core at about 30°, plunge in axis of core.

**DEFORMATION:** Porphyroclastic zones at 110-130 cm. Piece 3A has a contact with undeformed gabbro, indicates the shear zone cuts the core at a shallow angle. Some elongation and incipient foliation in Pieces 3C and 3D. A brittle fracture in Piece 1G. Several fractures now filled with green amphibole in upper part of core.

**PRIMARY MINERALOGY:**

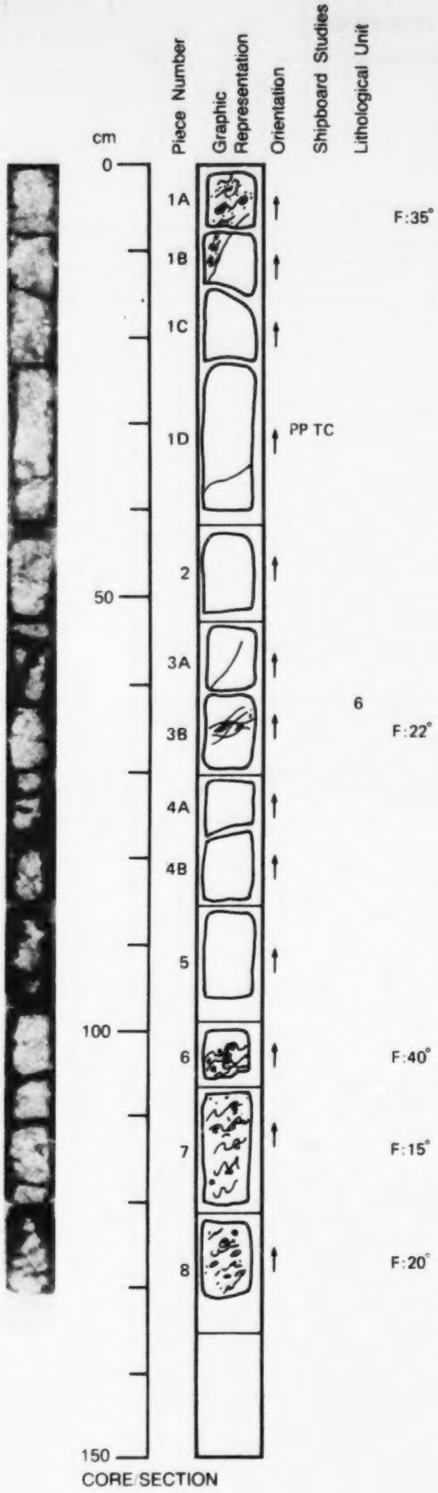
Plagioclase—Mode: 50%-60%.
Crystal size: 3-9 mm.
Crystal shape: Usually anhedral, also subhedral granular.
Preferred orientation: None apparent.
Percent replacement: Not determined.

Clinopyroxene—Mode: 30%-40%.
Crystal size: 2-10 mm, rarely to 20 mm.
Crystal shape: Subhedral to anhedral.
Preferred orientation: None apparent.
Percent replacement: Extensivly altered in upper part of core to amphibole.

Olivine—Mode: 5%-10%.
Crystal size: 2-6 mm.
Crystal shape: Anhedral, subrounded.
Preferred orientation: None apparent.
Percent replacement: Extensively altered to clay, magnetite, and amphibole.

**SECONDARY MINERALOGY:**

Total percent: Up to 30%.
Texture: Olivine pseudomorphed, particularly in top 100 cm, by clay, magnetite, and amphibole. Clinopyroxene partially to completely replaced by pale green amphibole, particularly in upper part of section. Large epidote feldspar patch on the back of Piece 3C.
Percent vein material: 5%-7%.
Vein material: Several amphibole, epidote veins, often associated with white albitized or granulated plagioclase, particularly at 25-35 cm and 120 cm. Numerous subhorizontal, streaky, white feldspathic veins (<1 mm wide).



118-735B-56R-4

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-8

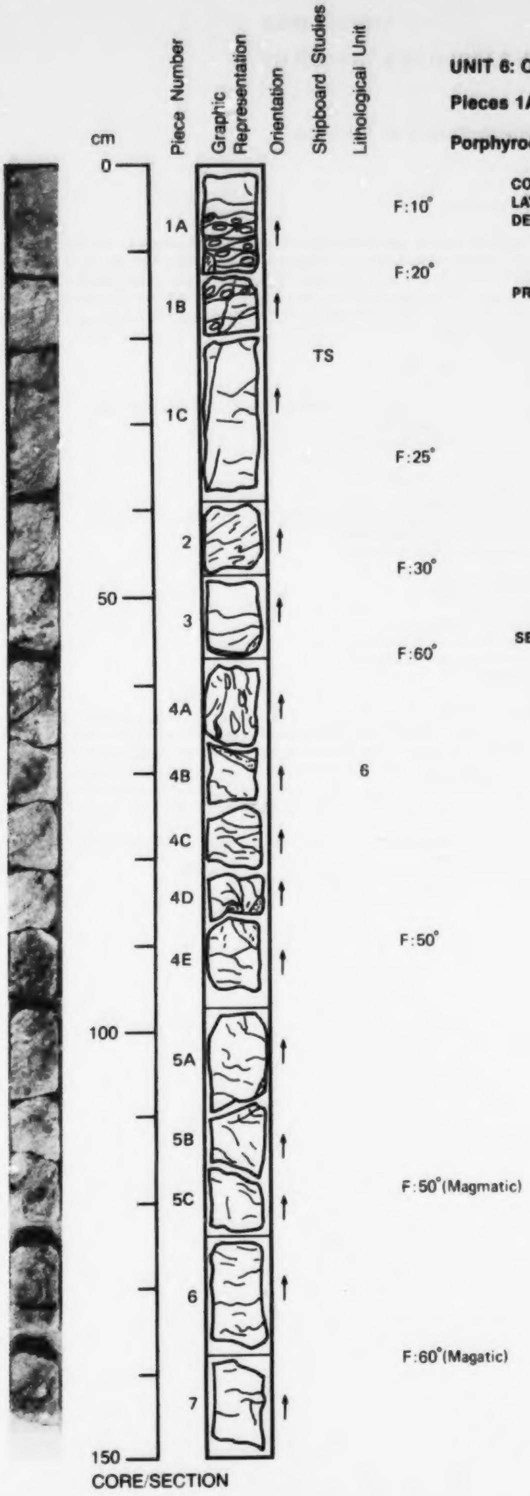
### Olivine Gabbro to Porphyroclastic Metagabbro

### Pieces 1A-8

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Between 0-12, 64-68, and 100-131 cm, olivine gabbro is deformed to a porphyroclastic metagabbro. Foliation defined by plastically deformed and recrystallized plagioclase, stretched augen of clinopyroxene.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 5-15 mm.
Crystal shape: Anhedral-subhedral.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Moderate to extensive.

Clinopyroxene—Mode: 40%.
Crystal size: 5-15 mm.
Crystal shape: Subhedral. Clinopyroxene brown and subophitically encloses plagioclase.
Preferred orientation: Locally in plane of foliation.
Percent replacement: Moderate to extensive.

Olivine—Mode: 4%-5%.
Crystal size: 3-4 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive.
**SECONDARY MINERALOGY:**
Total percent: 25% average, locally 90%.
Texture: Actinolite occurs in veins and occupies grain boundaries in undeformed areas. Alteration more extensive in deformed regions approximately 50%-90% of total. Plagioclase is recrystallized to neoblasts or albitized. Actinolite occurs along veins steeply inclined relative to foliation, particularly in Pieces 1D and 3A. Clinopyroxene is largely replaced by amphibole. Traces of sulfides and iron oxides (ilmenite?). Patches of talc(?) probably replace olivine. Elsewhere, olivine altered in typical meshlike fashion by black metallic mineral. Below 105 cm, iron oxides (ilmenite?) and sulfides are abundant and occur as layers parallel to foliation.
Percent vein material: 1%-2%.
Vein material: Actinolite.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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4B
4C
4D
4E
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5C
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7
TS
6
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F:20°
F:25°
F:30°
F:60°
F:50°
F:50°(Magmatic)
F:60°(Magatic)
CORE/SECTION

## 118-735B-86R-5

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1A-7

### Porphyroclastic Gabbro (Pieces 1-4A) and Massive Olivine Gabbro (Pieces 4B-7)

**COLOR:** Greenish gray.
**LAYERING:** Not apparent.
**DEFORMATION:** Foliation is clearly visible in the upper part of the section. Porphyroclastics of clinopyroxene and plagioclase are stretched and elongated. Grain size varies from <1 mm to 1.5 cm; decreased from original by a factor of 2. (Average diameter of grain in massive gabbro 7 mm.)

**PRIMARY MINERALOGY:**

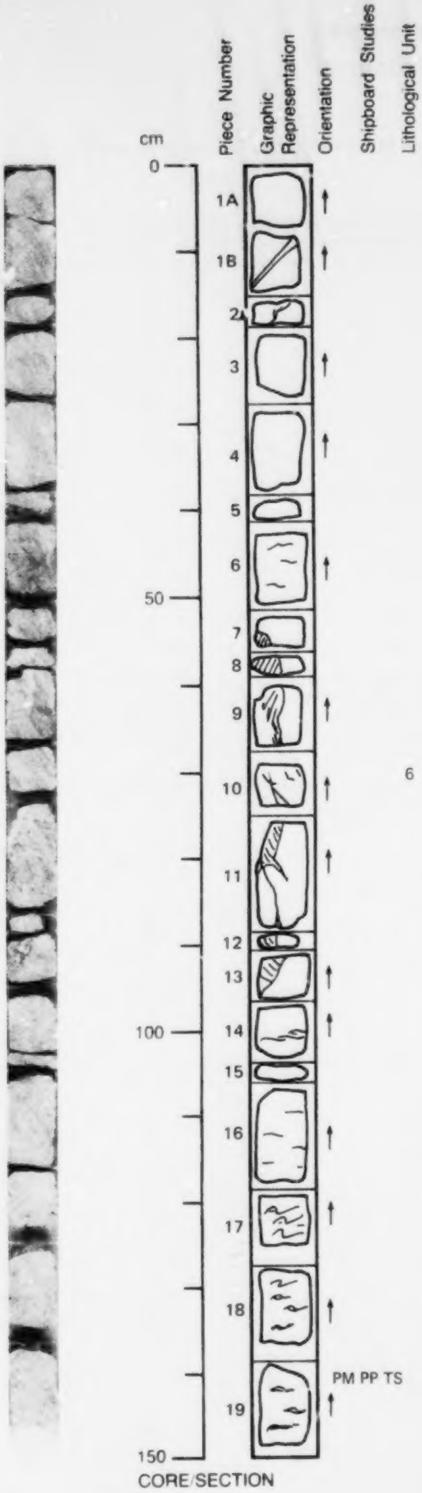
Plagioclase—Mode: 40%-60%.
Crystal size: <1-4 mm.
Crystal shape: Euhedral.
Preferred orientation: Visible.
Percent replacement: None.

Clinopyroxene—Mode: 30%-50%.
Crystal size: 1-17 mm.
Crystal shape: Oikocrystic, anhedral.
Preferred orientation: Strong to none.
Percent replacement: <90% by brown and green amphibole.

Olivine—Mode: 1%-5%.
Crystal size: 1-3 mm.
Crystal shape: Anhedral, lenses.
Preferred orientation: Not seen.
Percent replacement: Slight.

**SECONDARY MINERALOGY:**

Total percent: 30%.
Texture: Clinopyroxene is severely replaced (90%) by brown and green amphibole in porphyroclastic gabbros. Ilmenite-magnetite impregnation is abundant in Pieces 1C and 2 and is accompanied by sulfides (chalcopyrite mostly). Late cracks are filled with chlorite, carbonate, and amphiboles. Olivine is surrounded by bluish talc; magnetite makes a web pattern in the grains. Plagioclase is albitized in Pieces 3, 4A and 4B.
Percent vein material: 3%.
Vein material: Veins are filled with plagioclase, actinolite, and sparse pale yellow brown epidote.



**118-735B-86R-6**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-19**

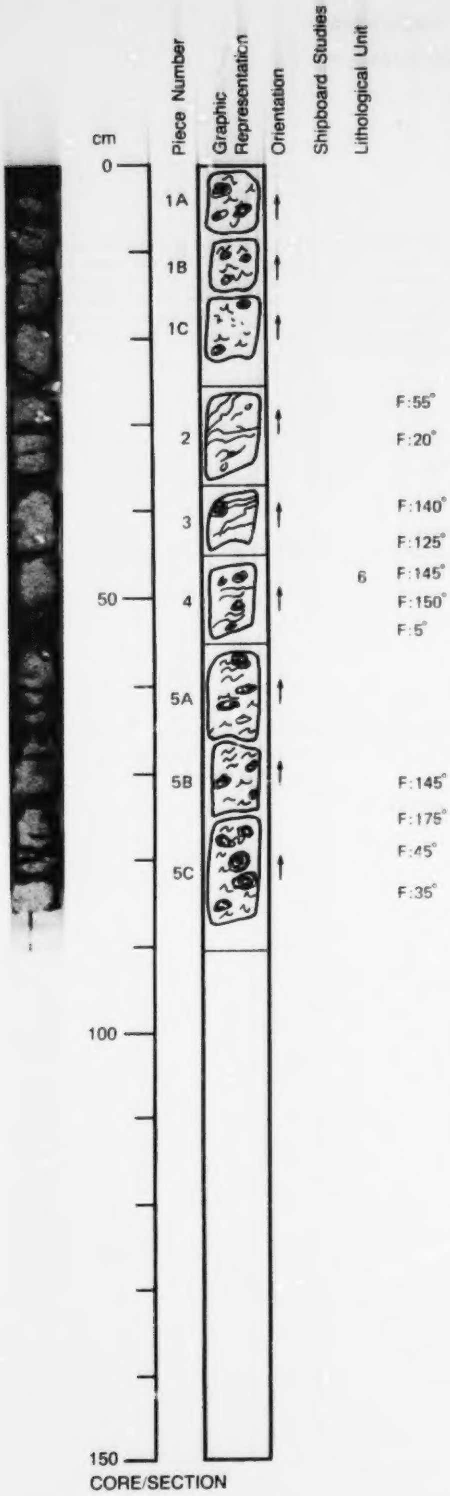
### Clinopyroxene-Poor Olivine Gabbro to Troctolite

**Pieces 1A-19**

**COLOR:** Gray to gray and white.
**LAYERING:** None.
**DEFORMATION:** Slight deformation and some granulation of plagioclase in upper 50 cm. 50-95 cm i fractured and veined. Some shear and offset on the fractures which are filled by feldspathi material. In Piece 9 a troctolite and coarser olivine gabbro are juxtaposed along a fracture 130-150 cm: gabbro is porphyroclastic, with 0.5-2 cm clinopyroxene porphyroclasts, 2-3 mm elongate olivine clasts. "Tails" of oxides from porphyroclasts and oxide-rich zone in Pieces 8 and 19—mylonitic matrix.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 40%-60%.
Crystal size: 3-8 mm.
Crystal shape: Euhedral to subhedral, enclosed partially by clinopyroxene.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 3-30 mm.
Crystal shape: Large subhedral grains, smaller anhedral and ophitic grains.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 5%-10%.
Crystal size: 2-10 mm.
Crystal shape: Subhedral.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: 40%.
Texture: Small crystalline aggregates on surface in Pieces 11 suggest growth into void. Some of the crystals are quite delicate and the aggregates are friable. These occur in Pieces 7-13. In Piece 12, clinopyroxene is often replaced by a granular green aggregate of epidote or amphibole. The olivine are replaced by dark mesh aggregates (talc-tremolite-magnetite). Piece 2 is extensively amphibolitized with dark, clayey, olivine pseudomorphs. A feldspathic vein cuts Piece 1B at a high angle. Some of the clinopyroxene in the upper part is quite green.
Percent vein material: 5%.
Vein material: Up to 3 cm wide veins of feldspar, diopside, sphene, actinolite, and both green and pinkish-brown epidote.
**COMMENTS:** Where undeformed, similar to Core 118-735B-85R.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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1A
1B
1C
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F:5°
5A
5B
F:145°
F:175°
F:45°
5C
F:35°
100
150
CORE/SECTION

**118-735B-86R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

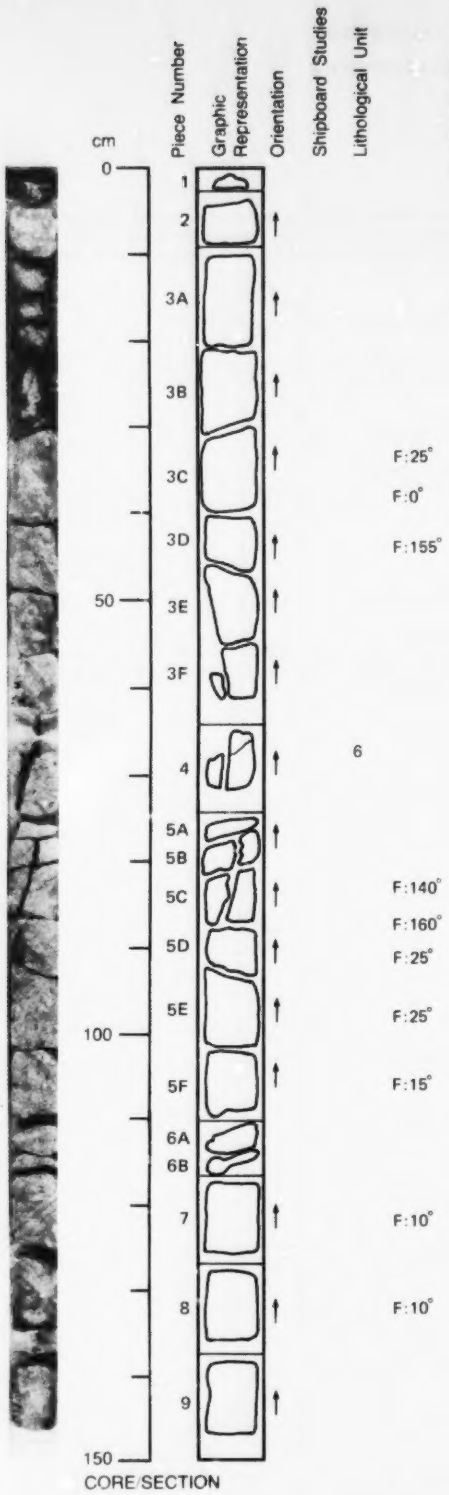
### Pieces 1A-5C

### Porphyroclastic Metagabbro

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic texture. Foliation defined by stretched and partially recrystallized plagioclase. Large augen of clinopyroxene throughout, 1-4 cm. A few similarly large augen of plagioclase. Original grain sizes difficult to estimate but sizes of pyroxene augen suggest coarse-grained.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: Variable, augen up to 1-4 cm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate to extensive.

Clinopyroxene—Mode: 38%-47%.
Crystal size: Variable, augen up to 1-4 cm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate to extensive.

Olivine—Mode: 2%-3%.
Crystal size: Variable.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive to complete.
**SECONDARY MINERALOGY:**
Total percent: Moderate to extensive.
Texture: Olivine partially to totally altered to dark clay minerals. Actinolite occupies grain boundaries and fractures. Ilmenite common to abundant throughout, forming layers parallel to foliation. Traces of sulfides throughout.
Percent vein material: None.
Vein material: None.


cm
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Lithological Unit
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F:25°
F:0°
F:155°
F:140°
F:160°
F:25°
F:25°
F:15°
F:10°
F:10°
CORE/SECTION

## 118-735B-87R-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-9**

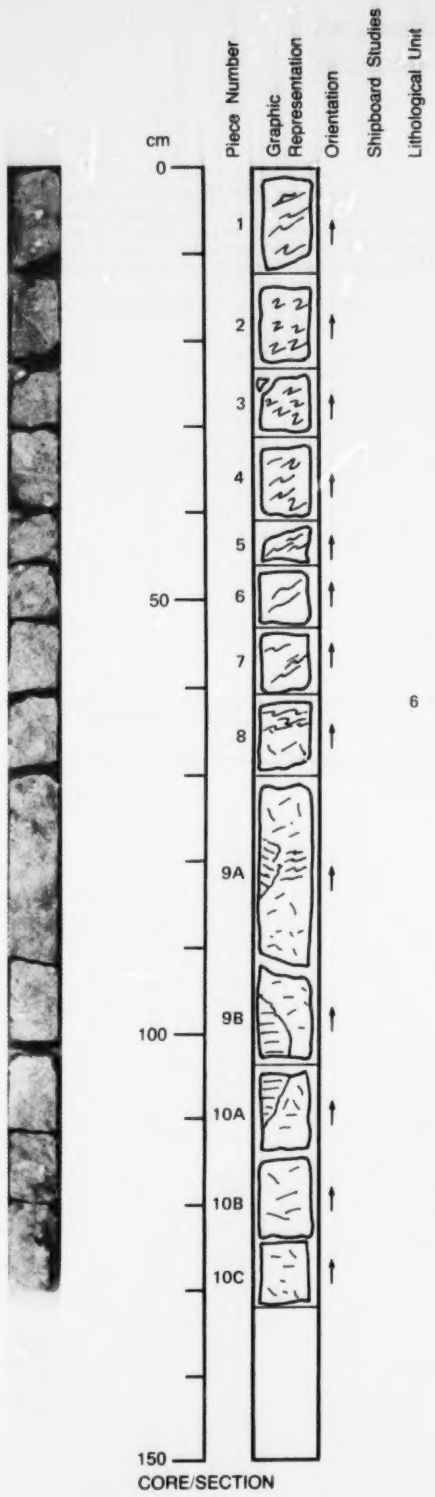
**Porphyroclastic Metagabbro**

**Pieces 1-9**

**COLOR:** Gray.
**LAYERING:** None.
**DEFORMATION:** Porphyroclastic texture. Foliation defined by stretched and partially recrystallized plagioclase and clinopyroxene. Foliation in Pieces 2, 3A, and 3B difficult to assess because of exceedingly large grain size: clinopyroxene >8 cm long. Orientation of these pyroxenes is steep (65°-70°) and may actually represent a primary growth feature since crystals still have a subhedral to euhedral outline. Remainder of section is finer-grained and foliation more apparent. Dips range from 0° to 160°. Because of deformation, original grain sizes and shapes difficult to estimate. Aspect ratio of plagioclase near 1:4.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 45%.
Crystal size: <0.5-4 cm.
Crystal shape: Anhedral.
Preferred orientation: In plane of foliation.
Percent replacement: Moderate.

Clinopyroxene—Mode: 51%-52%.
Crystal size: <0.5-4 cm.
Crystal shape: Anhedral to euhedral.
Preferred orientation: In plane of foliation, locally steeply inclined to foliation.
Percent replacement: Moderate.

Olivine—Mode: 3%-4%.
Crystal size: 3-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Extensive.
**SECONDARY MINERALOGY:**
Total percent: 50%-75%.
Texture: Iron oxides, probably ilmenite, common in layers parallel to foliation. Actinolite common along grain boundaries and fractures. Olivine partially to totally replaced by dark clay mineral.
Percent vein material: <1%.
Vein material: Amphibole on thin fractures.



## 118-735B-87R-2

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1-10C**

**Olivine Gabbro**

**Pieces 1-10C**

**COLOR:** Gray to green-white where veined.

**LAYERING:** At least two coarse to fine transitions, partially obscured by alteration. Pieces 10B to 9A (bottom), very coarse-grained to fine-grained. Pieces 9A (top) to 8, coarse-grained to medium-grained.

**DEFORMATION:** Small shear zones at top of Piece 8, and at 80 cm in Piece 9A. Probably some plagioclase granulation near deformed zones. The top 60 cm is porphyroclastic mylonite to porphyroclastic gabbro with oxides throughout and extensive amphibolitization. Foliation dips about 10°-20°, and there are pyroxene augen to 1.5 cm.

**PRIMARY MINERALOGY:**

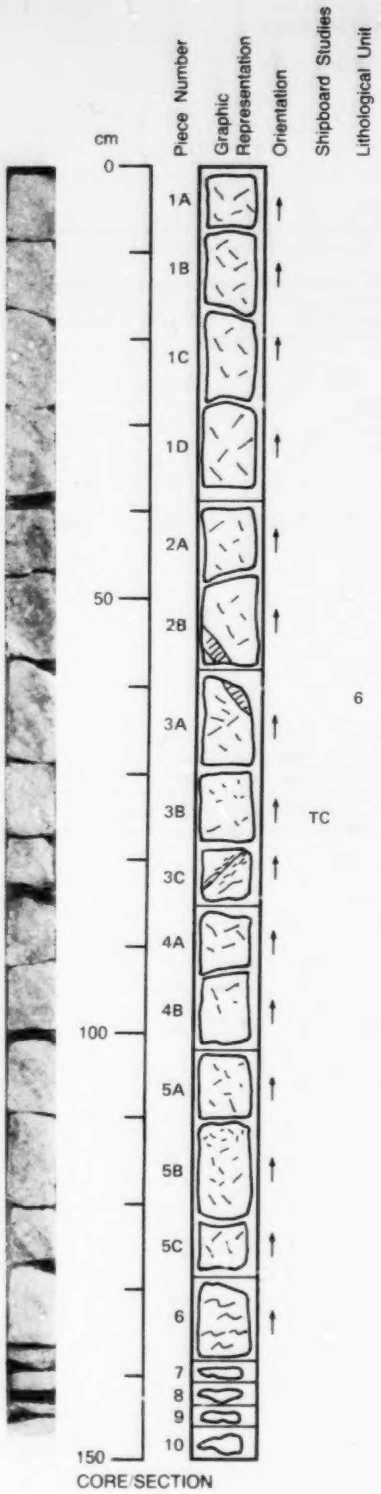
Plagioclase—Mode: 50%-70%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral, euhedral.
Preferred orientation: None observed.
Percent replacement: 30%-50%.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral, cumulus(?) grains in coarse sections, ophitic to poikilitic in finer-grained sections.
Preferred orientation: None observed.
Percent replacement: 30%-50%.

Olivine—Mode: 2%-8%.
Crystal size: 3-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None observed.
Percent replacement: 30%-50%.

**SECONDARY MINERALOGY:**

Total percent: Various.
Texture: Two large-veined, feldspathic zones (78-85 cm and 90-110 cm). Contacts on cut plus cored surfaces suggest the upper zone is a horizontal layer, the lower zone a lens or pod. Minerals in them include a white milky feldspar, actinolite, and minor epidote; oxides associated with both zones, particularly near margins of lower one. Some amphibolitized clinopyroxene from original rock also present in veined zones. Plagioclase may be in large part original and is granulated and possibly albitized in place, rather than being a magmatic vein.
Percent vein material: 5%-7%.
Vein material: See above.



**118-735B-87R-3**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-10**

**Olivine Gabbro**

**COLOR:** Light gray, white-gray in vein.

**LAYERING:** Several grain-size variations, coarse- or very coarse-grained to medium- and fine-grained sections. Coarse-grained sections usually have subhedral, cumulus appearing pyroxene; in the finer-grained sections the pyroxenes are usually ophitic to poikilitic. Pieces 5C to 5A, coarse-grained to fine-grained. Pieces 4A to 3A (bottom), coarse-grained to fine-grained. Pieces 3A (top) to 2A, coarse-grained to medium-grained. Pieces 1D to 1A, very coarse-grained to medium- to coarse-grained.

**DEFORMATION:** Porphyroclastic texture developing in Piece 6. Pieces 7-10 are porphyroclastic mylonite.

**PRIMARY MINERALOGY:**

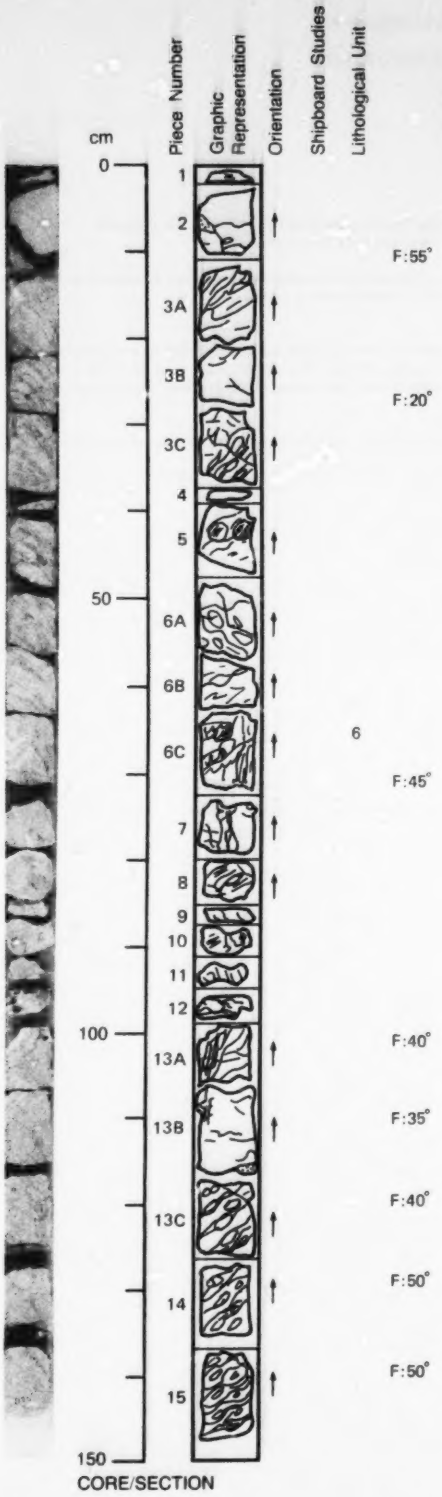
Plagioclase—Mode: 50%-70%.
Crystal size: 2-15 mm.
Crystal shape: Subhedral, euhedral.
Preferred orientation: None observed.
Percent replacement: 10%-30%.

Clinopyroxene—Mode: 25%-40%.
Crystal size: 2-15 mm.
Crystal shape: Textures as noted above.
Preferred orientation: None observed.
Percent replacement: Variously amphibolitized.

Olivine—Mode: 2%-8%.
Crystal size: 3-6 mm.
Crystal shape: Anhedral.
Preferred orientation: None observed.
Percent replacement: Usually altered in part.

**SECONDARY MINERALOGY:**

Total percent: Various.
Texture: Magnetite-talc-amphibole(?) mesh after olivine common. Extensive amphibolitization of clinopyroxene in Pieces 3B and 3C, associated with crosscutting amphibole vein.
Percent vein material: Not determined.
Vein material: 14-mm-wide feldspathic vein at 55-64 cm, largely feldspar with actinolite and minor epidote.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Piece Number
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Orientation
Shipboard Studies
Lithological Unit
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CORE/SECTION
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**118-735B-87R-4**

**UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE**

**Pieces 1-15**

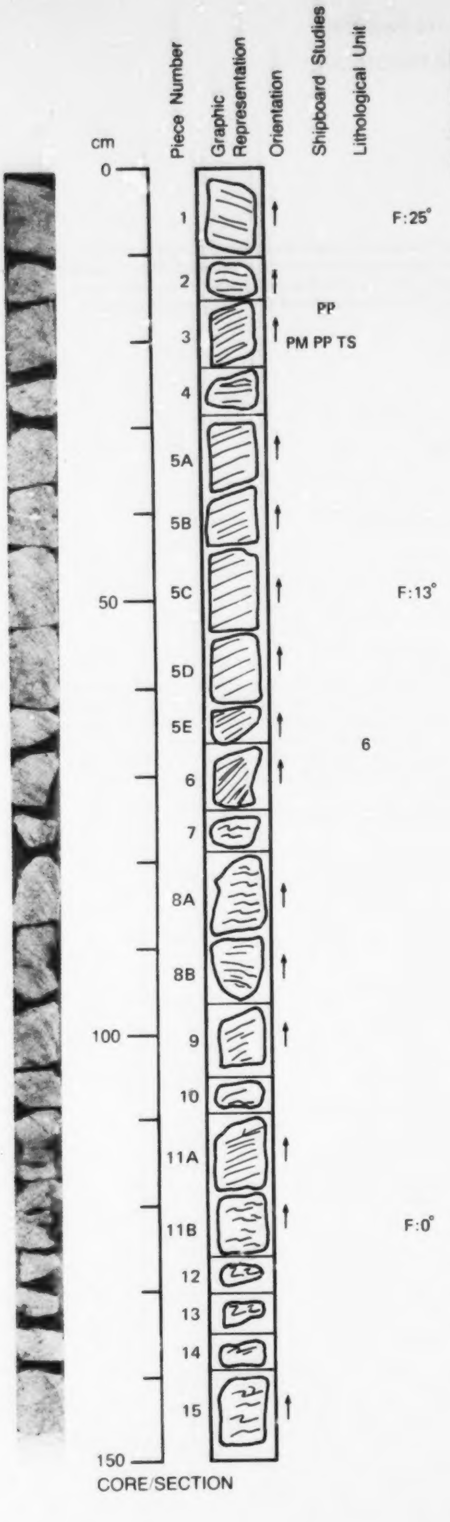
**Porphyroclastic Olivine-Poor Gabbro**

**Pieces 1-15**

**COLOR:** Grayish green.
**LAYERING:** Not apparent.
**DEFORMATION:** Present in every piece. The foliation plane is sometimes diffuse or deflected by pyroxene porphyroclasts. The plagioclase is deformed and recrystallized into neoblasts that are transposed into the foliation planes. Oxides are also injected along the foliation planes. Tensional cracks oblique to the foliation are observed in pyroxene and plagioclase.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 50%-60%.
Crystal size: 2-5 mm.
Crystal shape: Anhedral.
Preferred orientation: Visible.
Percent replacement: Slight.

Clinopyroxene—Mode: 40%-50%.
Crystal size: 3-15 mm.
Crystal shape: Anhedral.
Preferred orientation: Visible.
Percent replacement: 50%-80% by amphibole.

Olivine—Mode: 1%-5%.
Crystal size: <2 mm.
Crystal shape: Anhedral.
Preferred orientation: Visible.
Percent replacement: Slight.
**SECONDARY MINERALOGY:**
Total percent: Variable, 10%-45%.
Texture: Coronitic, pseudomorphic. Olivine is replaced by brown clays and green chlorite. Pyroxene is largely replaced by amphibole of different colors: brown in center, dark green at rims, and grass green near veins or cracks. Oxides (ilmenite + magnetite) are massively injected in Pieces 3B, 3C, 5, 6A, 13A, 13B, and 14. Chalcopyrite is associated with these zones (5%-20% oxides) as is grass green amphibole. Veins are filled with a mixture of sodic plagioclase and actinolite. Veinlets filled with green amphibole and white clays(?).
Percent vein material: 8%.
Vein material: Plagioclase, actinolite, amphibole, and white clays(?).


cm
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F:0°
6
CORE/SECTION

**118-735B-87R-5**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

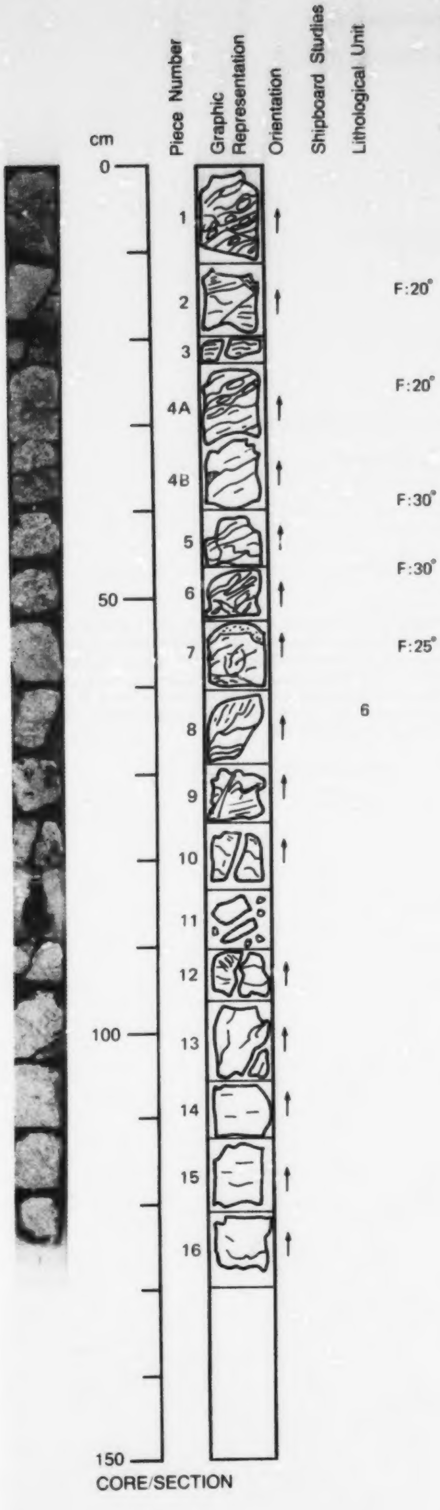
**Pieces 1-15**

**Porphyroclastic Mylonite**

**Pieces 1-15**

**COLOR:** Green-gray.
**LAYERING:** Some coarse to fine grain-size variations are preserved (Piece 8, for example).
**DEFORMATION:** Intensely mylonitized, porphyroclasts up to 6 mm.

**PRIMARY MINERALOGY:** Rock was an olivine gabbro, no reasonable mode can be estimated. Relict olivine and olivine pseudomorphs apparent in hand sample.
**SECONDARY MINERALOGY:**
Total percent: Up to 70%.
Texture: Extensive amphibolitization of clinopyroxene. Olivine replaced by dark magnetite clay and amphibole pseudomorphs. Oxides common throughout, >5% at 10-15, 33-48, and 56-57 cm. Clinopyroxene porphyroclasts common but almost no plagioclase porphyroclasts (all recrystallized).
Percent vein material: 3%-5%.
Vein material: Subhorizontal white, streaky, veins (<1 mm wide) common, hornblende ± plagioclase.



**118-735B-87R-6**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1-16

### Porphyroclastic Olivine Gabbro (Pieces 1-6), Poorly Foliated Olivine Gabbro (Pieces 7-12) and Undeformed Troctolite (Pieces 13-16)

**COLOR:** Grayish green with some orangish brown spots from place to place.

**LAYERING:** Not present.

**DEFORMATION:** Limited to the upper part of the section (Pieces 1-6); other pieces affected little by plastic deformation. Plastic deformation is well defined by flattened pyroxene and plagioclase. Oxides injected along the foliation and neoblastic plagioclase, forming bands up to 5 mm thick. Plagioclase and amphibole veins and cracks are oblique to the foliation. Grain size varies from 1.5 cm (large porphyroclasts of pyroxene) to tenths of millimeter for plagioclase neoblasts.

**PRIMARY MINERALOGY:**

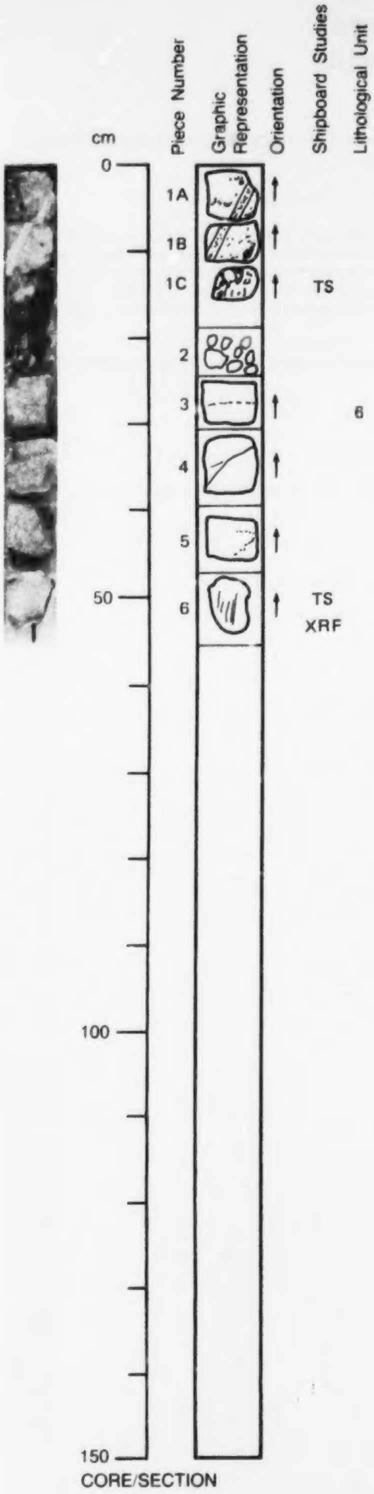
Plagioclase—Mode: 50%-60% (foliated olivine gabbro); 50%-60% (porphyroclastic olivine gabbro); 20%-80% (troctolite).
Crystal size: 1-5 mm.
Crystal shape: Euhedral.
Preferred orientation: Variable.
Percent replacement: Variable, slight to moderate.

Clinopyroxene—Mode: 35%-45% (foliated olivine gabbro); 40%-45% (porphyroclastic olivine gabbro); <5% (troctolite).
Crystal size: Up to 20 mm.
Crystal shape: Oikocrystic to anhedral.
Preferred orientation: Variable.
Percent replacement: 60% by brown and green amphibole.

Olivine—Mode: 5%-10% (foliated olivine gabbro); 1%-2% (porphyroclastic olivine gabbro); 20%-3% (troctolite).
Crystal size: 0.5-1.5 mm.
Crystal shape: Anhedral.
Preferred orientation: Not seen.
Percent replacement: Slight replacement by talc, magnetite, and clays.

**SECONDARY MINERALOGY:**

Total percent: Up to 50%.
Texture: Pseudomorphic. Porphyroclastic gabbros: Pyroxene is almost totally replaced by brown (center) to green amphibole (60%). Plagioclase is albitized in Pieces 4A, 4B, 5, and 6. Late veins are oblique to the foliation and are composed of amphibole or plagioclase and chlorite. Iron hydroxides are deposited in these veins. Ilmenite-magnetite are injected into the porphyroclastic gabbros. The oxides are associated with chalcopyrite and pyrite. They are present in Piece 10 (olivine-gabbro). Pentlandite is observed in intergrowths with oxides. Olivine in olivine gabbro and troctolite are replaced by talc and magnetite assemblages. Orangish brown clays are present in Pieces 6, 7, 8, 13, and 14. These are mixed with iron hydroxides. White streaks are filled with calcite and talc (in troctolite) and amphibole elsewhere.
Percent vein material: 2%-5%.
Vein material: Amphibole, plagioclase, and chlorite.



**118-735B-87R-7**

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

**Pieces 1A-6**

**Troctolite**

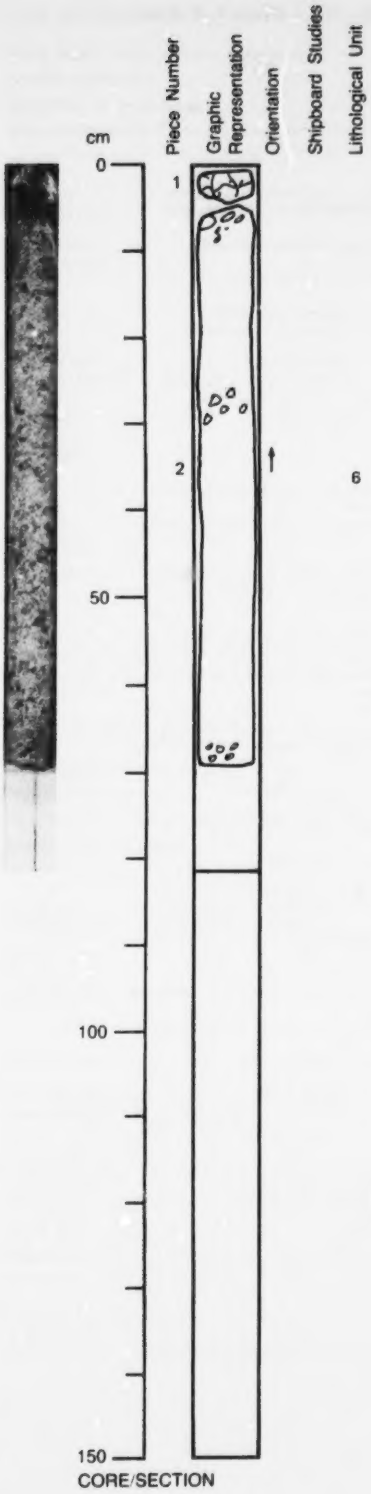
**Pieces 1A-6**

**COLOR:** Gray with orange spots.
**LAYERING:** None.
**DEFORMATION:** Possible auto-brecciation in Piece 1C.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 55%.
Crystal size: 5-10 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate.

Clinopyroxene—Mode: 2%-8%.
Crystal size: 1-10 mm.
Crystal shape: Anhedral (interstitial) to subhedral (poikilitic).
Preferred orientation: None.
Percent replacement: Moderate to extensive.

Olivine—Mode: 37%-43%.
Crystal size: 5-8 mm.
Crystal shape: Anhedral.
Preferred orientation: None.
Percent replacement: Moderate to extensive.

**SECONDARY MINERALOGY:**
Total percent: 30%-75%.
Texture: Amphibole occurs on all grain boundaries partially replacing plagioclase and olivine; also on numerous thin, nearly vertical fractures. Piece 6 is particularly intensely altered. Olivine is generally altered to an orange to yellow-brown oxide. In most pieces it is totally replaced. Some fresh olivine remains in partially altered areas of Pieces 3, 4, and 5. One large vein in Pieces 1A and 1B is composed of plagioclase and actinolite. Some iron staining on feldspar. Piece 1C has vugs filled by carbonate. Vein in Piece 4 is feldspar heavily stained by iron. Some ilmenite in this piece. Trace of sulfides in Piece 5.
Percent vein material: 5%-8%.
Vein material: Amphibole, sodic plagioclase, carbonate, and chlorite.



## 118-735B-88N-1

## UNIT 6: OLIVINE-RICH GABBRO AND TROCTOLITE

### Pieces 1 and 2

### Coarse Pyroxenite Intensely Veined with Amphibole and Plagioclase—Some Coarse Gabbro.

### Piece 1

**COLOR:** Green and white; very dark green.
**LAYERING:** None.
**DEFORMATION:** None.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: Only in veins and gabbro.
Crystal size: Up to 2 cm in coarse gabbroic material.
Crystal shape: Not determined.
Preferred orientation: None apparent.
Percent replacement: Not determined.

Clinopyroxene—Mode: Not determined.
Crystal size: Up to 3 cm.
Crystal shape: Not determined.
Preferred orientation: None apparent.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Colorless amphibole(?) associated with green amphibole. Talc—green coating on some surfaces.
Percent vein material: Not determined.
Vein material: Amphibole and plagioclase.

### Olivine Gabbro

### Piece 2

**COLOR:** Dark gray with greenish gray or dark gray patches, locally dull orange (after olivine).
**LAYERING:** Both size and crude-phase layering observed.
**DEFORMATION:** Minor. Tiny vertical and oblique fractures at 20-25 and 30-35 cm.
**PRIMARY MINERALOGY:**
Plagioclase—Mode: 20%-60%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Clinopyroxene—Mode: 40%-70%.
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.

Olivine—Mode: 0%-15% (approximately 15% between 25-35 cm).
Crystal size: Not determined.
Crystal shape: Not determined.
Preferred orientation: Not determined.
Percent replacement: Not determined.
**SECONDARY MINERALOGY:**
Total percent: Not determined.
Texture: Amphibole widely distributed. Local albitized zones (near 29-30 cm), red oxides after olivine in pyroxenite and at base of core.
**COMMENTS:** Primary mineralogy ranges modally from nearly pyroxenitic to almost leucogabbro. This core was drilled using the Navi-drill and is unsplit.
Percent vein material: Not determined.
Vein material: Not determined.

## THIN SECTION DESCRIPTION

**118-735A-1D-1 (Piece 1, 1-3 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine(?) | — | 5 | | | Anhedral | Entirely replaced by talc, clay minerals, carbonate, and opaques. |
| Plagioclase | 22 | 60 | 10 | | | Fractured and recrystallized into small grains, porphyroclasts. |
| Clinopyroxene | 22 | 35 | 4 | | | Partially recrystallized and replaced by green hbd. |
| Hornblende | < 1 | < 1 | | | | Patches in cpx. Uncertain if igneous or metamorphic origin. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Ol(?) | Cores of replacement of mafic mineral thought to be ol. |
| Carbonate | < 1 | Ol(?), veins | As veins in the plag. |
| Albite | 1 | Plag | Fills sealed, pre-deformation fractures in the plag. |
| Actinolite | 3 | Plag, hbd | Post-deformation replacement. |
| Hornblende | 25 | Cpx, veins | Occurs as replacement of cpx porphyroclasts, and in veins which cut the porphyroclasts. Green hornblende is also recrystallized during deformation. |
| Plagioclase | 20 | Plag | In the most deformed zones, plag is recrystallized in grains < 0.07 mm, often with straight grain boundaries. |
| Talc | 1 | Ol(?) | Replacing mafic mineral (ol?). |
| Opaques | 1 | | Cores replacing ol(?) and intergrown with cpx, rutile(?). Trace of ilmenite with hematite exsolution lamellae in cpx unevenly cut by amphibole. Also minor Fe-oxyhydroxides. |

**COMMENTS:** 1) The deformation occurred with recrystallization of green hornblende and plag. High temperature and/or strain rate (highly deformed zones with very small grain sizes). The total strain is not very high.

2) Two types of cpx are observed: one with cleavage and extensive replacement by green hornblende; one clear with reddish brown inclusions, worm-like or straight, and patches of brownish hornblende—not replaced by green hornblende.

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 4, 26-30 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic, mylonitic

**GRAIN SIZE:** Medium

**OBSERVER:** STA/CAN/OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 59 | 59 | < 1-2 | | Anhedral | Present as porphyroclasts in matrix. |
| Clinopyroxene | 20 | 35 | 0.1-≈4 | | Anhedral | Present as distorted porphyroclasts, replaced by amphibole and clay. |
| Ilmenite | — | 1 | < 0.1 | | Anhedral | Stretched and flattened showing foliation. Polycrystalline. |
| Hornblende | 3 | 3 | | | Anhedral | Inclusions in cpx. |
| Orthopyroxene | — | 2 | 1.5 | | Anhedral | Replaced by tremolite ± talc(?) aggregate. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Cpx | Smectite mixed with Fe oxide. |
| Carbonate | 1 | (?) | Present with smectite + Fe oxide. Anhedral. |
| Tremolite | 2 | ??? | White to pale green. Large euhedral crystal. |
| Hornblende | 9 | Cpx | Green-brown to pale brown. Replaces cpx. Recrystallized. |
| Opaques | 1 | Cpx | Ilmenite, magnetite. Replaces cpx. Bands in mylonite. Ilmenite concentrated toward center of section, near porphyroclasts. |
| Amphibole | 3 | ?? | Blue. |

**COMMENTS:** 1) Two amphiboles. Pale brown replaces cpx porphyroclasts. Green to green-brown as recrystallized mosaic.

2) 1% bright blue amphibole.

3) Tremolite ± talc replaces ol(?), opx(?).

4) Plagioclase is recrystallized.

5) Two different zones are recognized. One is fine-grained (0.1-0.4 mm cpx and plag porphyroclasts) mylonitic zone. The other is coarse-grained (≈5 mm cpx, plag, brown hbd after cpx(?) porphyroclasts and < 0.5 mm neoblasts of plag, cpx and amphibole) porphyroclastic zone.

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 3, 19-21 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Variable, fine to medium (0.04-4.00 mm)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 56 | 1-4 | | Elongated | Deformed porphyroclasts. |
| Clinopyroxene | — | 40 | 1.5-3.0 | | | |
| Ilmenite | Tr | Tr | 1 | | | Partially altered to magnetite. |
| Amphibole | Tr | 3(?) | 0.5 | | | Pleochroic anhedral interstitial grains. Late magmatic and rapidly destabilized into secondary brown amphiboles. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Cpx | Yellow to yellow-brown. Replaces cores of altered cpx. |
| Hornblende | 7 | Fractures, cpx | Replaces brown hornblende. Pale green to blue-green. Restricted to grain boundaries and fractures. |
| Plagioclase | 46 | Plag | Replaces plag phenocrysts. Granoblasts (0.4-0.8 mm) formed by crushing and neoblasts (<0.05 mm) formed by recrystallization. In the groundmass or as inclusions in large plag crystals. |
| Ilmenite, magnetite | 2 | Ilmenite, cpx | Small grains (0.04-0.15 mm) included in replaced cpx along cleavage planes.<br>Outlines talc polygons in altered cpx. |
| Amphibole | 8 | Amphibole | Brown amphibole. In shear planes in ancient cpx, at grain outer margins, or as pockets in groundmass (or altered cpx). |
| Clinopyroxene | 27 | Cpx | Small granoblasts (≈0.4 mm) forming a mosaic near large, now altered cpx. Magnetite outlines the shapes of the granoblasts. These granoblasts are in turn replaced by actinolite or pale brown amphibole. |

**COMMENTS:** Plastically deformed metagabbro; deformation of phenocrysts and development of neoblasts and granoblasts. Metamorphism under static hydrous conditions (hornblende, brown amphibole). Open fractures filled by amphibole.

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 12, 78-82 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Gabbroic with minor cataclasis at edges

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30.9 | 50 | 10-15 | | | Fractures in plag filled by amphibole and minor clay minerals. |
| Clinopyroxene | 13.0 | 40 | 10-13 | | | Partially replaced by brown amphibole. Opx exsolution in cpx replaced by orange-brown material, similar to replacement of primary opx. Also cross cut by veins of colorless amphibole. |
| Orthopyroxene | — | 10 | | | | Replaced by orange-brown material. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10.1 | Opx(?) | Dark orange-brown, cryptocrystalline masses mixed with magnetite. |
| Carbonate | Tr | Opx | In area of opx alteration |
| Hornblende | 15.6 | Cpx, groundmass | Occurs mainly replacing cpx and in masses between plag. Brown. |
| Plagioclase | 8.5 | Plag | Neoblasts. |
| Ilmenite, magnetite | 4.4 | Opx, plag | In areas of opx alteration and as small inclusions in plag. |
| Hornblende | 5.9 | Hbd, fractures | Green. Replaces brown hornblende along edges of cpx and fills fractures in plag. |
| Amphibole | 11.3 | Opx | Colorless. Occurs in masses adjacent to altered areas that were originally opx. In some cases, forms acicular crystals growing perpendicular to edges of opx alteration area. |

**COMMENTS:** Percentages based on >500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 14, 90-92 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 17 | 55 | 0.2-2.0 | | Anhedral | Porphyroclasts. Deformation twins. |
| Clinopyroxene | 6 | 39 | <6 | | | Crystals often bent. Replaced by amphibole. |
| Orthopyroxene | Tr | 6 | 4 | Bronzite | Subhedral | Altered to clay, hematite, aragonite, and tremolite |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Opx | Replacing opx pseudomorphs. |
| Carbonate | Tr | Opx | In opx pseudomorphs. |
| Actinolite | 2(?) | Veins | Possibly some in veins and around grain boundaries. |
| Hornblende | 19 | Cpx | Green, well crystallized hornblende. Often cutting cpx. Post deformation. |
| Plagioclase | 36 | Plag | Recrystallized neoblasts, <0.1 mm in size. |
| Tremolite | 4 | Opx | Fine-grained clear needles. |
| Hematite | Tr | Opx | In pseudomorphs. Blood red. |
| Magnetite | 1 | Px | In both opx and cpx pseudomorphs. |
| Clinopyroxene | 2 | Cpx | Neoblasts. |
| Ilmenite(?) | Tr | ? | Tails on augen. |

**COMMENTS:** Opaques: some patchy ilmenite; much finer magnetite mainly in alteration amphibole. Trace of Fe oxyhydroxides.
Percentages based on 1000 point counts:
Plag porphyroclasts 16.8; plag neoblasts 36.4; cpx 6.3; alteration products of cpx 10.9; cpx neoblasts 2.3; opx 1.2; opx alteration products 5.4; opaques 0.8; hematite 0.1; other (veins) 1.0.

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 19, 117-120 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 23.1 | 64 | 0.4-12 | | Anhedral | Deformation twinning. Elongate in the plane of foliation. |
| Clinopyroxene | 2.2 | 33 | 0.1-0.4 | | Anhedral | Replaced by brown and green amphibole. Some granulation along grain boundaries of some porphyroclasts. |
| Ilmenite | 3.3 | 3 | 0.3-0.5 | | Equant | Occurs as clusters of equant crystals in layers parallel to foliation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 41.2 | Plag | Neoblasts. |
| Brown hornblende | 21.6 | Cpx | |
| Green hornblende | 8.6 | Hbd. cpx | Replaces brown amphibole and cpx. |

**COMMENTS:** Percentages based on 530 point counts.
Original igneous texture destroyed by deformation and amphibole replacement. Brown amphibole appears to have replaced cpx first along grain boundaries and in patches associated with oxide inclusions. Brown amphibole was later partially replaced by green amphibole. In one area of granulated cpx, there are traces of a low to medium relief, low birefringent, colorless mineral which is associated with amphibole (probably tremolite).

## THIN SECTION DESCRIPTION

**118-735B-1D-1 (Piece 23, 141-143 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 60 | 0.2-2.0 | | Anhedral | Porphyroclasts. |
| Clinopyroxene | 15 | 40 | | | | |
| Orthopyroxene | <1 | 5(?) | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 15 | Cpx | Light green to green fibrous grains or rims around cpx clasts. Also with finer-grained cpx clots. |
| Hornblende | 5 | Cpx | Green and brown. Small scattered bits in cpx. |
| Plagioclase | 30 | Plag | <0.1 mm neoblasts. |
| Hematite | 1 | Opx | In cores of opx pseudomorphs. |
| Ilmenite/ magnetite | 1 | Opx | In cores of opx pseudomorphs. Also in cpx clots. |
| Clinopyroxene | 3 | Cpx | Recrystallized neoblasts. |

**COMMENTS:** Foliation defined by cpx-plag lenses.
Oriented thin section, cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118-735B-1D-2 (Piece 1, 2-9 cm)**

**ROCK NAME:** Metagabbro augen gneiss

**WHERE SAMPLED:**

**TEXTURE:** Augen gneissic

**GRAIN SIZE:** Medium

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 1 | 60 | 1-3 | | Augen | Surrounded by recrystallized plag. |
| Clinopyroxene | 4 | 37 | 1-3 | | Augen | |
| Orthopyroxene | <1 | 3 | | Hypersthene | | Occasional relict augen in schlieren. |
| Oxides | Tr | Tr | | Fe-Ti | | Occasional small grains in groundmass. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Opx | |
| Hornblende | 15 | Cpx | Brownish green to green. |
| Plagioclase | 59 | Plag | Flattened neoblasts of recrystallized primary plag. |
| Orthopyroxene | 1 | Opx | Schlieren of hypersthene neoblasts replacing primary hypersthene along foliation. |
| Amphibole | 9 | Cpx | Green and clear amphiboles. At least three generations. |
| Clinopyroxene | 9 | Cpx | Neoblasts of recrystallized primary cpx. |
| Hematite | <1 | Oxides, opx | Stains altered silicates. Occasional grains in groundmass. |

**COMMENTS:** Well developed foliation defined by flattened plag neoblasts, aligned secondary hbd, hypersthene schlieren and stretched pods of recrystallized cpx. One third of the thin section is heavily altered to hbd in proximity to hydrothermal veins cross cutting the foliation at a steep angle. Concentration of relatively coarse hbd occurs along and near veins.

## THIN SECTION DESCRIPTION

**118-735B-1D-2 (Piece 13, 86-90 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 14 | 56 | 2-5 | | | Porphyroclasts. Often very flattened. |
| Clinopyroxene | 26 | 37 | 2-5 | | | Porphyroclasts with mortar texture. |
| Orthopyroxene | 2 | 5 | 0.5-2.0 | Hypersthene | | Occurs often as flattened porphyroclasts. |
| Ilmenite | 2 | 2 | | | | Occurs as irregular lenses and bands (1 mm thick) along the foliation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Opx | Reddish brown clay. Replaces opx lamellae in cpx. |
| Carbonate | < 1 | Opx | Clots in opx pseudomorphs. |
| Hornblende | 1 | Cpx | Brown hbd blebs in cpx. |
| Plagioclase | 42 | Plag | Neoblasts formed by recrystallization of primary plag |
| Phlogopite | < 1 | Opx | Occurs as small books in opx schlieren along foliation. |
| Clinopyroxene | 4 | Cpx | Recrystallized syndeformational neoblasts. |
| Amphibole | 7 | Cpx, veins | Replacing and rimming cpx. Also in veins which cross cut plag, and sometimes the foliation. |

**COMMENTS:** Cpx and brown to green hbd are intergrown in recrystallized mosiac and in layers. Mylonitic bands are very fine grained.

## THIN SECTION DESCRIPTION

**118-735B-2D-1 (Piece 14, 76-80 cm)**

**ROCK NAME:** Well foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Variable, fine to medium (0.2-2.0)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 50 | 60 | 0.5 | | Polygonal | |
| Clinopyroxene | 2 | 38 | 0.5-2.0 | | Subhedral | Largely replaced by green-brown amphiboles. Some crystals were porphyroclasts before replacement. |
| Amphibole | Tr | 1(?) | 0.2-0.5 | | Irregular | Brown. Patches in or at the margins of altered cpx. Associated with ilmenite. |
| Ilmenite | Tr | 1 | < 0.3 | | Irregular | Opaques included in cpx. Associated with brown amphiboles. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Cpx, amphibole | Yellow-brown. Associated with mixture of poorly crystallized hematite and Fe hydroxides. |
| Tremolite/ actinolite | 5 | Cpx | Possibly replacing opx. Well-developed thin (0.1 mm) needles in reaction zone. Intergrown with magnetite. |
| Hornblende | 27 | Cpx | Green-brown pseudomorphs after cpx. |
| Plagioclase | 10 | Plag | Neoblasts, 0.01-0.06 mm. |
| Amphibole | 4 | Amphibole | Blue-green rims (0.04 mm thick) around green-brown hbd. Fibrous. Also replacing a number of grains. |
| Magnetite | 1 | Cpx | Possibly replacing opx. Minute grains or irregular grains in reaction zone with actinolite-tremolite. |
| Amphibole | 1 | Cpx, amphibole | Brown. Small pale brown patches enclosed in green-brown amphiboles, 0.02-0.20 mm. |
| Hematite | TR | Ilmenite | Fe hydroxide. See clays. |

**COMMENTS:** Distribution of plag is irregular and one area of the thin section is leucocratic.
Some plastic deformation and foliation developed.
Amphibolitization of cpx (possibly opx was present with actinolite + magnetite). Brown to green-brown.
Blue-green amphibole developed as rims and fillings of late fractures.

## THIN SECTION DESCRIPTION

**118-735B-2D-1 (Piece 21, 113-115 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic to mylonitic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine(?) | — | (?) | | | | Talc-tremolite pseudomorphs. Possibly after opx(?). |
| Plagioclase | 5 | 37 | 0.25–1.00 | | Anhedral | Porphyroclasts. |
| Clinopyroxene | 5 | 60 | 1–4 | | Flattened | Porphyroclasts. |
| Orthopyroxene(?) | — | 2(?) | ≈1 | | Rounded | Talc-tremolite pseudomorphs. Possibly ol(?). |
| Ilmenite | 1(?) | 1(?) | | | Anhedral | Cannot distinguish primary from secondary ilmenite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Cpx, opx(?), ol(?) | Smectite mixed with Fe oxide. |
| Carbonate | <1 | Opx(?), ol(?) | Late replacement of opx (ol?). |
| Tremolite | (?) | Opx(?), ol(?) | |
| Hornblende | 15 | Cpx | Brown. Replacing cpx and in mosaic. |
| Plagioclase | 31 | Plag | Fine grained mosiac of recrystallized grains. |
| Hornblende | 1 | Plag, hbd | Green. Along boundaries between plag + hbd or cpx. |
| Clinopyroxene | 25 | Cpx | Recrystallized in mosaic. Neoblasts. |
| Ilmenite | 7 | Cpx | Bands with brown hbd. Ilmenite has hematite exsolution lamellae, locally intergrown with Fe oxyhydroxides. |
| Talc | 1 | Opx(?), ol(?) | Opx (ol?) pseudomorphs with tremolite. |

**COMMENTS:** 1) Neoblasts of brown hbd and px are mixed with ilmenite in bands.
2) Rounded pseudomorphs of talc + tremolite or hematite, calcite and smectite may be opx.

## THIN SECTION DESCRIPTION

**118-735B-2D-1 (Piece 24, 135-149 cm)**

**ROCK NAME:** Mylonite to porphyroclastic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic to porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 45(?) | 0.1–0.2 | | Anhedral | Nearly all recrystallized. |
| Clinopyroxene | 8 | 45(?) | 0.2–4.0 | | Anhedral–subhedral | Partially recrystallized, also replaced by amphibole. |
| Ilmenite | — | 5(?) | <0.5 | | | Aggregates of small grains. Associated with opx. |
| Orthopyroxene | 2 | 5 | 0.2–0.5 | | Elongate, anhedral | Replaced by dark orange-brown to brown clay hematite clots. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 15 | Cpx, opx, veins | Estimate may be high. Replacing cpx or fine layers. Also filling veins. Zones of replacement often cross cut the foliation. |
| Hornblende | 5 | Cpx | Small pieces in larger cpx and in mafic layers after cpx. |
| Plagioclase | 40 | Plag | <0.01 mm mosaics of neoblasts, lenses and discontinuous layers. |
| Clinopyroxene | 15 | Cpx | Neoblasts. Cpx is just broken or replaced. Recrystallized grains are very fine. |
| Hornblende | 2 | Cpx, opx | Green. In fine-grained mafic layers after cpx. |
| Opaques | 8 | Spinel, cpx | Fine-grained and patchy aggregates. |

**COMMENTS:** The opaques are all secondary: mainly ilmenite, rare magnetite, and some Fe oxyhydroxides. Hematite exsolution in ilmenite. No sulfides present.
Prominent foliation defined by discontinuous layers 0.1–0.6 mm thick of plag neoblasts alternating with cpx-amphibole-magnetite layers. The opaques (mainly ilmenite) are very abundant. Large (>1 mm) porphyroclasts are concentrated in one layer.
Oriented thin section cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118-735B-2D-2 (Piece 1, 0-4 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 55 | 1-8 | | Anhedral | Porphyroclasts. Undulose extinction. Fractured. |
| Clinopyroxene | 10 | 45 | 1-4 | | Anhedral | Bent and fractured porphyroclasts. |
| Orthopyroxene | < 1 | | | | | Large exsolution(?) in deformed cpx. Possibly primary, but uncertain. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 2 | Cpx, amphibole | Some rims and clots on edges of cpx and other amphiboles. |
| Hornblende | 23 | Cpx, veins | Green. Some green to blue-green. Patches and blades replacing cpx and in veins cross cutting foliation. |
| Plagioclase | 35 | Plag | < 0.1 mm mosaic of neoblasts. Some actinolite on boundaries. |
| Clinopyroxene | 5 | Cpx | Neoblasts(?). Probably recrystallized from porphyroclasts. |
| Magnetite | 2 | Opx, cpx | In altered px cores and schlieren. |
| Hornblende | 3 | Cpx | Brown. Small patches in cpx. |

**COMMENTS:** Note: ilmenite and magnetite are both present. Some albitized plag also present.
Well defined foliation defined by plag-cpx lenses. Cpx commonly fractured and rotated. Most of the amphibole appears to be post deformational since this mineral occurs in veins which cut the foliation and in grain boundaries with parallel orientations.

## THIN SECTION DESCRIPTION

**118-735B-2D-2 (Piece 17, 99-101 cm)**

**ROCK NAME:** Poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2 | | | | |
| Plagioclase | 50 | 65 | | | Anhedral | Twinned. Orthocumulate. |
| Clinopyroxene | 10 | 22 | | | | |
| Hornblende | 1 | 1 | | | | Blebs in px. |
| Orthopyroxene | 2 | 10 | | | | Lamellae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | < 1 | Fractures | Mixed with Fe oxide in microfractures. |
| Carbonate | 1 | Opx | Mixed with hematite. |
| Actinolite | 2 | Plag, cpx, opx | Grain boundaries with plag. |
| Hornblende | 10 | Cpx | Green-brown to red-brown. Syndeformational and in late veins, recrystallized. |
| Plagioclase | 13 | Plag | Neoblasts. |
| Clinopyroxene | 2 | Cpx | Neoblasts with hbd. |
| Fe oxide | 1 | Opx | Mixed with clay |
| Tremolite | 5 | Opx | Around opx pseudomorphs. |
| Talc | > 1 | Opx | Mixed with tremolite around opx pseudomorphs. |
| Opaques | 1 | Cpx | Rods. Probably magnetite in altered cpx lamellae. Some Fe oxyhydroxides after ol. Trace patches of ilmenite. Grain boundary magnetite; some in flaky brown amphibole with exsolution lamellae. |

**COMMENTS:** 1) Calcite-Fe oxide pseudomorphs with high temperature reaction coronas of tremolite and actinolite. Probably replacing ol (possibly opx; assumed ol for percent static replacement). Ol was later altered to oxides.
2) Only a few poorly defined deformed recrystallized zones.

## THIN SECTION DESCRIPTION

**118-735B-2D-2 (Piece 19B, 116-120 cm)**

**ROCK NAME:** Foliated olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Layered(?)

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.7 | 12.3 | 2–7 | | Anhedral | Irregularly distributed in thin section. Possibly layered (see diagram). |
| Plagioclase | 55.1 | 68.1 | 2–12 | | Subhedral–anhedral | Irregularly distributed in thin section. Possibly layered (see diagram). |
| Clinopyroxene | 10.7 | 19.6 | 2–15 | | Anhedral | Irregularly distributed in thin section. Possibly layered (see diagram). |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite(?) | 1.4 | Plag | Forms low birefringent mineral next to plag. Around tremolite which jackets or completely replaces ol. |
| Plagioclase | 13 | | Neoblasts, <2 mm in size. |
| Clinopyroxene | 0.4 | | Neoblasts, <1 mm in size. |
| Tremolite | 3.2 | Ol | |
| Hornblende | 8.6 | Cpx | Some may be primary. |
| Hematite | 0.8 | Ol | |
| Talc | 1.7 | Ol | |
| Magnetite(?) | 0.8 | Ol | |
| Amphibole | 0.6 | Plag | |

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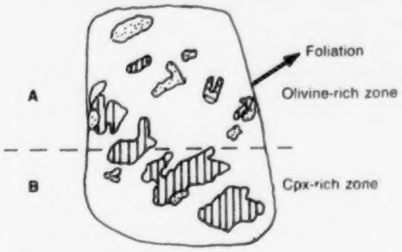
**COMMENTS:** Percentages based on 3000 point counts.
Normalized percentages for parts A and B of the thin section:

| | A | B |
|---|---|---|
| Plagioclase | 70.8 | 54.3 |
| Clinopyroxene | 15.5 | 39.9 ← ▥ |
| Olivine | 13.7 | 5.8 ← ◌ |

Igneous layering is normal to the foliation.



## THIN SECTION DESCRIPTION

**118-735B-3D-1 (Piece 2, 7-11 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

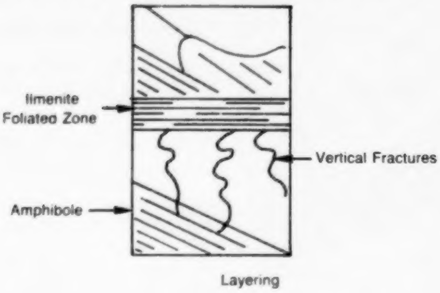
**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 45 | 0.1–1.0 | | Anhedral | Small, very elongate fragments of original grains. |
| Clinopyroxene | 8 | 55 | <0.1 | | | Unaltered patches in amphibolitized porphyroclasts. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | Pale green. Fine dusting in plag and in between some amphibole crystals. |
| Hornblende | 30 | Cpx, veins | Green to brown. Replacing cpx and in veins. In places, completely replaces cpx in lenses and veins with parallel grains. |
| Actinolite | 12 | Cpx, veins | Fine fibrous aggregates and some cpx replacements. In some veins, in part replacing an early amphibole. |
| Plagioclase | 23 | Plag | Mosaic of <0.1 mm neoblasts. |
| Opaques | 5 | Cpx | Anhedral grains near cpx replacements. Fine-grained aggregates in a mafic layer in central part of the slide. Mainly patchy ilmenite. Traces of magnetite in finer grained amphibole. Traces of Fe oxyhydroxides. |

**COMMENTS:** This rock is extensively replaced. Most of the cpx is replaced by amphibole. Parts of the rock have interlocking, semi-parallel amphibole aggregates. The amphibole appears to be late syndeformational to post-deformational. This rock is intermediate, with respect to percent alteration, between the fresh porphyroclastic gabbros of 735B and the amphibolites of site 733.



## THIN SECTION DESCRIPTION

**118-735B-3D-1 (Piece 9, 46-49 cm)**

**ROCK NAME:** Mylonitic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine, with augen up to 3.5 mm

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 40 | 0.5–2.4 | | Elongated, rounded | Porphyroclasts, rotated during deformation. Strained, recrystallized. |
| Clinopyroxene | 8 | 60 | 1–2 | | Elongated, deformed | Porphyroclasts, rotated during deformation. Strained, recrystallized. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Amphibole | Reddish brown patches in amphiboles. |
| Actinolite | 10 | Cpx | Very fine needles localized in thin bands replacing amphibole. Intergrown sometimes with plag neoblasts. |
| Hornblende | 7 | Amphibole | Brown. In pressure shadows or in green amphibole. |
| Plagioclase | 35 | Plag | Neoblasts, 0.02–0.08 mm. Intergrown with actinolite or in monomineralic bands, 0.1–0.4 mm wide, parallel to the foliation plane. |
| Green hornblende | 30 | Cpx | Porphyroclasts, 1.0–3.5 mm. Replaced by brown amphibole. Slight brown color, euhedral to augen-shaped. |
| Clinopyroxene | 5 | Cpx | Neoblasts, 0.1–0.3 mm. Disseminated in mylonitic bands. Partially amphibolitized. |
| Opaques | Tr | ?? | Ilmenite and magnetite. Grains <0.04 mm, in foliation planes. |

**COMMENTS:** Strong deformation of gabbroic protolith. Composition uncertain. For example, opx may have been present, now replaced by actinolite. Brown amphibole replaces cpx. Green-grown amphibole replaces cpx (blue-green in plag). Actinolite replaces green-brown amphibole.

## THIN SECTION DESCRIPTION

**118-735B-3D-1 (Piece 11, 58-60 cm)**

**ROCK NAME:** Porphyroclastic to poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic, granular

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 55 | 0.2-2.0 | | Anhedral | Porphyroclasts. Most small, slightly stretched crystals with sutured boundaries. Average size 0.4-0.5 mm. |
| Clinopyroxene | 8 | 45 | <4 | | Anhedral | One crystal only slightly altered. Other fragments are in larger altered cpx clots. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | Plag, cpx | Along grain boundaries and fractures. Rarely replacing cpx. |
| Actinolite | 10 | Cpx | Pale green fibrous aggregates in cpx pseudomorphs. Also in veins. |
| Sphene | Tr | Ilmenite | Reaction after ilmenite. |
| Hornblende | 19 | Cpx | Green fibrous aggregates of <0.1-0.2 mm, after cpx and in veins. |
| Plagioclase | 12 | Plag | Recrystallized neoblasts <0.1 mm. |
| Opaques | 1 | Cpx | Anhedral, 0.01-0.10 mm crystals. Usually ilmenite after cpx. |
| Hornblende | 5 | Cpx | Small, <0.1 mm, strings in cpx. Also rimming cpx. |

**COMMENTS:** End of minicore. Thin section possibly cut in the plane of foliation.

## THIN SECTION DESCRIPTION

**118-735B-3D-1 (Piece 14, 82-85 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Holocrystalline, hypidiomorphic-granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 45 | | | | Deformed and partially recrystallized to subgrains, 0.4-0.8 mm in size, and to neoblasts, <0.05 mm in size. |
| Clinopyroxene | 30 | 50 | | | | Partially replaced by amphibole, clay minerals, and minor hematite along exsolution lamellae. Some granulation at grain boundaries. |
| Orthopyroxene | — | 5 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays, hematite | 8 | Cpx, opx | Replacing opx along exsolution lamellae in cpx, and replacing opx. |
| Plagioclase | 25 | Plag | |
| Magnetite | 1 | Opx, cpx, veins | Occurs as rod-like inclusions along exsolution lamellae, in veins with clays(?), and in patches of opx replacement minerals. |
| Brown amphibole | 4 | Cpx | Patchy replacement of cpx. |
| Green amphibole | 9 | Amphibole, veins | Replacing brown amphibole, and in fractures/veins. |
| Hematite | 1 | Opx, cpx | Replacing opx, in veins, and in cpx. |
| Colorless amphibole | 2 | Opx | Occurs in patches around edges of opx replacement, and as overgrowths on brown amphiboles. |

**COMMENTS:** Opx is possibly an ol pseudomorph.

## THIN SECTION DESCRIPTION

**118-735B-4D-1 (Piece 10, 64-68 cm)**

**ROCK NAME:** Mylonite

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 35 | >3 | | Anhedral | Porphyroclastic. |
| Clinopyroxene | 3.2 | 35 | 2-3 | | Anhedral | Completely replaced by green amphibole in half of the thin section. Partially replaced by hematite + clay minerals in the other half. |
| Ilmenite | 23.2 | 30 | 0.1-1.6 | | Equant | Occurs as inclusions in primary cpx. Predominately as small crystal aggregates/layers. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Sphene | 1 | Ilmenite | Sphene after ilmenite. |
| Plagioclase | 8.4 | Plag | Neoblasts. |
| Plagioclase | 19.0 | Plag | Porphyroclasts composed of neoblasts, surrounded by oxides. |
| Hematite | 6.4 | Cpx | Interstitial. Partially replacing cpx. |
| Hematite, clays | 7.4 | Ilmenite | Hematite exsolution lamellae in ilmenite. |
| Green amphibole | 7.8 | Cpx | Interstitial. |
| Green amphibole | 24.6 | Cpx | Replacing cpx. |
| Magnetite | Tr | Cpx | Traces of fine magnetite in altered cpx. |

**COMMENTS:** Although texture is apparently mylonitic, cpx is not strongly deformed. Cpx occurs as equant to slightly elongate, rounded crystals set in a fine matrix of oxides + plag neoblasts. Plag porphyroclasts are also rounded, but consist of fine aggregates of plag neoblasts rather than large, deformed solitary crystals.

Ilmenite predominates in the section of the slide where amphibole completely replaces cpx. In this part of the slide, the assemblage is dominated by ilmenite + amphibole (after cpx). In the other end of the slide, abundance of plag increases, occurring as porphyroclasts composed of neoblasts. Here, the cpx is only partially replaced by a mixture of hematite + clay(?) and the abundance of opaque minerals with exsolution (i.e. magnetite with hematite exsolution) increases.

Percentages based on 500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-4D-1 (Piece 12, 78-82 cm)**

**ROCK NAME:** Poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulus modified into granoblastic

**GRAIN SIZE:** Coarse, up to 7 mm

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 42 | 0.5-2.5 | | Euhedral | Enclosed in px or in the matrix. Strongly recrystallized into granoblasts. |
| Clinopyroxene | 10 | 55 | 0.2-7.0 | | Subhedral | Also cumulus phase and in pore space of the cumulate. Almost completely replaced by amphibole. |
| Brown amphibole | 1 | 3(?) | <0.3 | | Irregular | Clear, strongly pleochroic. Irregularly distributed in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Amphibole, cpx | Yellow brown to dark brown. Occupies the center of cpx crystals. |
| Tremolitic actinolite | 12 | Cpx | Well developed, fine-grained needles of radiating bundles, especially at the margin of cpx (some entire grains replaced). Possibly intermixed with talc(?). |
| Hornblende | 24 | Cpx, fracture | Green-brown pseudomorphs after cpx. Idioblastic in late-stage vein. |
| Plagioclase | 22 | Plag | Granoblasts. Straight edges, triple junctions, recrystallized large primary plag crystals. |
| Clinopyroxene | 5 | Cpx | Granoblasts (0.5 mm) recrystallized large primary cpx crystals. |
| Amphibole | 2 | Cpx, amphibole | Blue-green. Rimming green-brown amphibole and filling late-stage open fractures. |
| Magnetite | 1 | Cpx | By-product replacement with tremolitic actinolite. |

**COMMENTS:** Polygonal recrystallization of larger plag grains and cpx. Cpx is replaced by green-brown amphibole and tremolitic actinolite pale magnetite(ancient opx(?) if talc is present).

Green-brown amphibole and tremolite actinolite are replaced by blue-green amphibole.

Veins filled by green-brown amphibole (idioblastic). Dark color. 1-6 mm in size

Clay alteration of amphibole.

## THIN SECTION DESCRIPTION

**118-735B-4D-2 (Piece 4, 7-9 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Foliated

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 65 | 0.5-2.0 | | Flattened | Porphyroclasts. |
| Clinopyroxene | 2 | 29 | 1-2 | | Flattened | Porphyroclasts with blebs of cpx. |
| Ilmenite | 1 | 1 | 0.5 | | Anhedral | Large grains. |
| Hornblende | 1 | 1 | <1 | | Anhedral | Inclusions in cpx. Some could be secondary. |
| Orthopyroxene | — | 4 | 1 | | Flattened | Could have been replaced by cummingtonite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | | In lense with earlier formed opaques surrounded by tremolite. Post deformation. Chlorite follows a fracture oblique to foliation. |
| Epidote | Tr | | Fine-grained. |
| Actinolite | 11 | Cpx, opx | Actinolite + cummingtonite(?). Colorless to green. Post deformation. |
| Hornblende | 17 | Cpx | Brown-green. Syndeformational. Also in vertical cracks in plag. |
| Opaques | 1 | Opx | Probably magnetite after opx. Traces of patchy ilmenite. Fine magnetite in white amphibole patches (probably after opx). |
| Plagioclase | 25 | Plag | Crushed and recrystallized. |

**COMMENTS:** 1) Brown to green hbd is syndeformational. Occurs as neoblasts and in vertical fractures in plag and cpx. (N.B. Formation of vertical fractures followed formation of mylonitic zones.)
2) Pale actinolite-tremolite is later, static replacement of px. Cogenetic with chlorite and bluish amphibole.
3) Bluish amphibole fills late veins and forms outer corona on pseudomorphs.

## THIN SECTION DESCRIPTION

**118-735B-4D-2 (Piece 1, 10-16 cm)**

**ROCK NAME:** Foliated gabbro-norite

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Variable. Original grains coarse (5 mm). Recrystallized fine to medium (0.01-4 mm).

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3 | 0.3 | | Elongated | Highly deformed and altered ol. Mixture of tremolite + abundant magnetite. |
| Plagioclase | 20 | 60 | 1-4 | | Elongated, deformed | Strained and elongated. Largely deformed and recrystallized. |
| Clinopyroxene | 6 | 29 | 0.5-4.0 | | Prismatic, deformed | Large phenocrysts deformed and altered into tremolitic actinolite and magnetite. |
| Orthopyroxene | 4 | 8 | <5 | | Prismatic | Large phenocrysts deformed and recrystallized. Obscured [illegible] clays and tremolite needles. |
| Brown amphibole | Tr | Tr | 0.04 | | Irregular | [illegible]ies, blebs in px. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Opx | Dark brown, pseudomorphs after op[illegible] |
| Chlorite | 1 | Opx | In coronas around opx pseudomorphs, next to plag. |
| Tremolitic actinolite | 8 | Opx, cpx | Pseudomorphs after px, associated with irregular to idioblastic magnetite. |
| Hornblende | 15 | Cpx, fracture | Green-brown. Pseudomorphs of small idioblastic grains in late stage open fractures. |
| Plagioclase | 40 | Plag | Granoblasts (up to 1 mm) and neoblasts (0.01-0.6 mm) derived from recrystallization of primary, large plag crystals. |
| Amphibole | 2 | Amphibole, fractures | Blue-green. Fibrous to prismatic. Distinctive pleochroic colors. Late stage alteration product. |
| Magnetite | 1 | Px, ol | Reaction product of replacement of px. 0.02-0.08 mm. |

**COMMENTS:** 1) Plastic deformation: kinking and recrystallization/deformation of plag, ol, and px.
2) Hydrothermal metamorphism: green-brown amphiboles replacing px, tremolitic actinolite replacing opx (+ magnetite).
3) Open fractures filled with green amphibole or blue-green amphibole.
4) Late stage: coronitic reaction after green-brown amphibole (rims) and filling fractures. Some green to brown amphibole also cuts blue-green amphibole.

**THIN SECTION DESCRIPTION** **118-735B-4D-2 (Piece 3, 24-29 cm)**

**ROCK NAME:** Mylonite/metagabbro

**WHERE SAMPLED:** At sharp contact between mylonite and mylonitic metagabbro

**TEXTURE:** Mylonitic, porphyroclastic

**GRAIN SIZE:** Very fine to coarse **OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| METTAGABBRO | | | | | | |
| Olivine | — | (?) | | | | |
| Plagioclase | 10 | 64 | 0.1-5 | | Anhedral | Mostly in the half of the thin section away from the mylonitic contact. |
| Clinopyroxene | 5 | 34 | 1-2 | | Anhedral | Relicts remaining in amphibolitized pseudomorphs. |
| Orthopyroxene | 1 | 2 | 2 | | Anhedral | Elongate layers altering to opaques. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| METAGABBRO | | | |
| Clays | 3 | Opx, cpx | Hematite-stained smectite in cores of some cpx crystals and possible opx pseudomorphs. |
| Clays | 4 | Plag | Pale tan. Coating grains in fine patches and filling fractures in large plag grains. More intense along boundary with mylonite and opaque-rich stringers. |
| Actinolite | 8 | Cpx | Pale green. Aggregates of needles after cpx. |
| Hornblende | 11 | Cpx | Green. After cpx in elongate layers. Also filling cross cutting veins. |
| Plagioclase | 50 | Plag | In lensoid aggregates of fine, <0.1 mm, neoblasts and as granular fragments. |
| Opaques | 8 | Cpx | Associated with amphibole clots and layers in both mylonite and metagabbro. Opaques in reflected light are white-gray with bright white lamellae; probably largely ilmenite with exsolution lamellae. |
| MYLONITE | | | |
| Plagioclase | 26 | Plag | Anhedral crystals, 0.01 mm in size. Granular aggregates with plag + amphibole. |
| Amphibole(?) | 24 | Cpx | Needles after cpx grains. Also equigranular pieces in groundmass. May includes cpx neoblasts. |
| Clinopyroxene | 8 | Cpx | Subrounded crystals. Cpx fragments partially replaced by smectite. |
| Plagioclase clasts | 3 | Plag | Subrounded crystals, 0.1-2.0 mm. Parallel to foliation. Often recrystallized to fine aggregates. |
| Hematite | 5 | | Staining smectite. Filling fractures which cross cut foliation. |
| Opaques | 26 | | Anhedral crystals, 0.02 mm. Granular texture with plag and amphibole. |
| Smectite | 8 | | Replacing cpx porphyroclasts. |

**COMMENTS:** Section includes sharp contact between a dark opaque-rich mylonite and a mylonitic metagabbro. The contact is very sharp. The metagabbro grades from mylonitic/porphyroclastic to coarse foliated metagabbro away from the contact. It appears to show increasing deformation across the slide through the transition to the very fine-grained opaque-rich mylonite. Mylonite is so fine-grained, foliation is only weakly defined. It is most noticeable where uncommon plag clasts are pulled out like taffy. Euhedral to subhedral plag occurs as inclusions in cpx porphyroclasts in mylonitic portion of the slide. Hematite veins in mylonitic portion taper out in metagabbro. Trace of carbonate in cores of hematite, replacing opx inclusions in cpx (mylonitic portion of slide)

## THIN SECTION DESCRIPTION

**118-735B-5D-1 (Piece 3, 10-13 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:**

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | 58 | <2 | | Anhedral | Porphyroclasts. Undulose extinction. Fractured and infilled by amphibole. Extensively replaced by green to brown amphibole and oxides. |
| Clinopyroxene | 10 | 40 | <2 | | Anhedral | |
| Orthopyroxene | — | 2 | | | Anhedral | Possibly ol. Replaced by tremolite + opaques. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Plag | Filling cracks in plag. Pale green to colorless. Radial aggregates. |
| Epidote | Tr | Plag | Filling cracks in plag. |
| Zoisite | Tr | Plag | Filling fractures in plag. |
| Actinolite | 12 | Cpx | Replacing cpx, rimming tremolite aggregates. Also occurs as thin layers which alternate with fine-grained plag mylonite layers. |
| Hornblende | 10 | Cpx | Brown-green. Replacing cpx. Brown hbd occurs as blebs in cpx. |
| Plagioclase | 43 | Plag | Neoblasts. |
| Tremolite | 5 | Opx (ol?), cpx | Flattened aggregates. Accompanied by opaques. |
| Ilmenite | 3 | Cpx | Occurs as inclusions in cpx, in thin mylonitic bands, and with tremolite aggregates. |
| Fe hydroxides | 1 | Veins | Filling cracks in amphibole and plag. |
| Hematite | Tr | Plag | Anhedral. In plag neoblastic matrix. |
| Apatite(?) | Tr | Plag | Clear, low birefringence, and fairly high relief. Possibly epidote(?). Forming a layer in fine-grained plag matrix. |

**COMMENTS:** Tremolite + opaques probably replacing opx or ol. Amphibole is extensively stretched and elongated to a 10:1 ratio.
Amphibole locally fills cracks perpendicular to foliation.
Ilmenite constitutes 2-3% and is concentrated in bands parallel to foliation. Minor fine-grained magnetite occurs in white/green amphibole patches.

## THIN SECTION DESCRIPTION

**118-735B-6D-1 (Piece 3, 12-14 cm)**

**ROCK NAME:** Augen gneissic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | 53 | 0.5–2.0 | | Lensoid | Porphyroclasts. |
| Clinopyroxene | 20 | 42 | 0.3–1.0 | | Flattened | Porphyroclasts. |
| Hornblende | 1 | 1 | | | Anhedral | Brown. Blebs in cpx. Possibly secondary. |
| Orthopyroxene | 1(?) | 4 | | | | Completely replaced by actinolite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Cpx | Replacing exsolution lamellae. |
| Carbonate | <1 | Fractures | Filling late fractures. Same generation as very pleochroic hbd. |
| Actinolite | 4 | Opx, cpx, hbd | Green to colorless. Forming pseudomorphs after px. |
| Hornblende | 10 | Cpx | Green to brown. Syndeformational. |
| Plagioclase | 38 | Plag | Neoblasts, 0.1–0.5 mm. |
| Clinopyroxene | 8 | Cpx | Neoblasts, ≈0.2 mm. |
| Ilmenite | 2 | Cpx | Bands define foliation. |
| Hornblende | <1 | Veins | Filling cracks perpendicular to foliation. Very pleochroic. Post deformation. |

**COMMENTS:** 1) Few thin, late veins perpendicular to foliation have very pleochroic hbd. May be different composition. Also subparallel carbonate veins.
2) Archive half of core has isoclinal fold not evident in this thin section from the working half of the core.
3) Some of the tremolite pseudomorphs could have been opx and could include cummingtonite.
4) Brown amphibole in cpx occurs as small patches which are optically continuous.

## THIN SECTION DESCRIPTION

**118-735B-6D-1 (Piece 13, 71-74 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Various, porphyroclasts 0.3-8.0 mm to neoblasts <0.1 mm **OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2 | ≈5 | | Anhedral | Possibly cpx. Replaced by tremolite + Fe oxide (hematite?) which are further replaced by pale green actinolite. |
| Plagioclase | 10 | 50 | <0.1-1.0 | | Anhedral | Porphyroclasts 0.3-1.0 mm, neoblasts <0.1 mm. Commonly veined by Fe oxides. Some amphibole veining. Porphyroclasts have amphibole pressure shadow. |
| Clinopyroxene | 21 | 48 | <0.1-8.0 | | Anhedral-subhedral | Replaced by greenish brown to brown hornblende. One grain has opx exsolution lamellae. Porphyroclasts have amphibole pressure shadow. |
| Orthopyroxene | Tr | <0.5 | ≈0.02 | | Anhedral | Exsolution lamellae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Cpx | Replacing cpx from the rim. |
| Actinolite<br>Tremolite | 5 | Cpx, ol | Euhedral laths, 0.05-0.10 mm. Ol is replaced by tremolite + Fe oxide at the cores which are surrounded by pale green actinolite. Smaller cpx grains are replaced by actinolite in opaque-rich zone. |
| Hornblende | 22 | Cpx | Color is variable: brown, green-brown, brownish green, green. Brown hbd usually occurs in the pressure shadow of cpx and inside the grain. Some px are completely replaced by brown hbd. Average size 0.1-0.4 mm. Crystals are generally tabular, granular. |
| Plagioclase | 40 | Plag | Neoblasts, <0.1 mm. |
| Opaques | 2 | Cpx | Ilmenite, hematite, Fe hydroxides, magnetite(?). Fine-grained, <0.02 mm hematite + magnetite(?) in cpx-rich zone. Probably derived from cpx by oxidation. Hematite or Fe hydroxides are also present with brown hbd. Crystals measure 0.1-0.2 mm. Euhedral magnetite is present in cpx. |

**COMMENTS:** 1) The replacement of cpx by hbd is fairly extensive except for some grains, one of which has opx exsolution lamellae.
2) Cpx and plag are commonly distorted and show wavy extinction. They have amphibole pressure shadows.
3) Ol pseudomorphs are extremely stretched. Aspect ratio = 1:10

## THIN SECTION DESCRIPTION

**118-735B-6D-1 (Piece 1B, 97-100 cm)**

**ROCK NAME:** Augen-gneissic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic, porphyroclastic

**GRAIN SIZE:** Fine, with porphyroclasts **OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 6 | 0.5 | | Anhedral | Talc-tremolite-hematite pseudomorphs. |
| Plagioclase | 25 | 50 | 1-3 | | Flattened | Porphyroclasts. Some twinning. |
| Clinopyroxene | 10 | 44 | 0.2-1.0 | | Flattened | Porphyroclasts. Originally oikocrysts. Dark inclusions. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 2 | Ol | Colorless to pale green. Static replacement of opx. Green on margins of plag. |
| Hornblende | 19 | Cpx | Brown amphibole occurs in patchy replacement of cpx; patches are optically continuous. Syndeformational. Green brown in mosaic with secondary cpx. |
| Plagioclase | 25 | Plag | Neoblasts. Some plag crystals are crushed. |
| Clinopyroxene | 15 | Cpx | Neoblasts, 0.2-0.4 mm. |
| Hematite | 4 | Ol | Cores of opx pseudomorphs. |

**COMMENTS:** 1) Some large crystals, in a fracture which runs through plag, are very pleochroic (colorless to green) hbd. Crystals are parallel to foliation and undeformed. Could be a static replacement of plag.
2) Some large, bent amphibole crystals look like cummingtonite after ol or opx.
3) Top 20% of slide is very fine-grained mylonite. No porphyroclasts in mylonite.

## THIN SECTION DESCRIPTION

**118-735B-6D-1 (Piece 19, 111-113 cm)**

**ROCK NAME:** Poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic, granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 28 | 53 | 0.2–2.0 | | Euhedral | Porphyroclasts. Undulose extinction. Fractured crystals. |
| Clinopyroxene | 3 | 39 | 0.5–2.0 | | Anhedral | Largely replaced by amphibole. |
| Orthopyroxene | <1 | 8 | 0.1 | | Anhedral | Fragments replaced by tremolite, opaques. Original grains range up to 3 mm in size. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | <1 | Cpx | In cpx pseudomorphs. |
| Actinolite | 19 | Cpx, veins | Pale part of cpx pseudomorphs. Also in veins. |
| Hornblende | 17 | Cpx, vein | Darker green than actinolite. After cpx and in vein. |
| Plagioclase | 25 | Plag | Neoblasts. Equigranular mosaic. Some nearly mylonitic zones. |
| Tremolite(?) | 5 | Opx | Clear pale green needles after opx. |
| Hematite(?) | 2 | Opx | Replacements in cores of opx pseudomorphs |

**COMMENTS:** Percentages based on 100 point counts. Tremolite/talc, hematite clot assumed to be primary opx. Green amphibole after cpx. Interstitial amphibole is not assignable to a protolith.
Modal percentages:
Plag clasts 28.1; plag neoblasts 25.3; opx 0.1; tremolite after opx 5.0; hematite after opx 2.0; cpx 2.9; amphibole after cpx 30.7; brown amphibole 0.1; interstitial amphibole 5.7; chlorite 0.1.
Some coarse granular cpx/plag aggregates between porphyroclastic sections.

## THIN SECTION DESCRIPTION

**118-735B-7D-1 (Piece 2A, 10-16 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | 55 | 1–4 | | Anhedral | Irregular extinction. |
| Clinopyroxene | 5 | 40 | 2–4 | | Rounded | Relict cores with rims of hbd and neoblasts. |
| Orthopyroxene | <1 | 5 | 1–4 | | Flattened | Replaced by tremolite-magnetite-talc |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Opx | In opx pseudomorphs. Mixed with hematite. |
| Zircon | <1 | | Euhedral crystals with high birefringence. |
| Actinolite/ tremolite | 22 | Cpx, opx | Pale green to white. High relief in opx pseudomorphs. |
| Hornblende | 12 | Cpx | Green-brown. Blocky, pale crystals. |
| Plagioclase | 40 | Plag | Neoblasts. |
| Clinopyroxene | 3 | Cpx | Neoblasts. |
| Talc | 1 | Opx | |
| Hematite | 1 | Opx | |
| Magnetite | 1 | Opx | In pseudomorphs. |
| Ilmenite | Tr | | In foliation planes with brown hbd. |

**COMMENTS:** 1) Late veins are filled with green hbd.
2) The replacement by green actinolite, tremolite + talc, and hematite are static replacements.
3) Magnetite is concentrated in hematite pseudomorphs.
4) The zircon-bearing gabbro is only slightly deformed and intruded into highly deformed foliated gabbro.

## THIN SECTION DESCRIPTION

**118-735B-7D-1 (Piece 9, 63-67 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 45 | 0.5–1.0 | | | Porphyroclasts. Twinned crystals. |
| Clinopyroxene | 17 | 50 | | | | Porphyroclasts. |
| Orthopyroxene | 3 | 5 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 5 | Opx, cpx | High relief. Rimming px. Post deformational. Also colorless replacement of opx. |
| Hornblende | 10 | Cpx | Brown to green. Neoblasts in mosaic. Syndeformational. |
| Plagioclase | 15 | Plag | Neoblasts. |
| Amphibole | 10 | Cpx, hbd | Green. Syn- to post-deformational. |
| Clinopyroxene | 10 | Cpx | Neoblasts. |

**COMMENTS:** 1) Strongly amphibolitized. Both syn- and post-deformational.
2) Small, high relief grains, possibly epidote.
3) Some primary igneous textures preserved between cpx and plag.

## THIN SECTION DESCRIPTION

**118-735B-7D-1 (Piece 10, 74-76 cm)**

**ROCK NAME:** Mylonitic to well foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic, porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 11 | 1.0–1.5 | | | Possibly opx. |
| Plagioclase | 8.4 | 48 | 1–4 | | Anhedral | Elongate crystals in the plane of foliation. Plastically deformed. |
| Clinopyroxene | 15 | 41 | 0.5–2.5 | | Anhedral | Equant to elongate crystals in the plane of foliation. Inclusions of Fe hydroxides and replacement by a mixture of hematite and clay along opx exsolution lamellae. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol | Clays + hematite replacing ol(?). |
| Carbonate | 1 | Ol | Carbonate + hematite replacing ol(?). |
| Plagioclase | 38.5 | Plag | Neoblasts. |
| Green amphibole | 21.8 | Cpx, amphibole | Replacing cpx along grain boundaries, in veins, and replacing brown amphibole. |
| Brown amphibole | 4 | Cpx | Replacing cpx. |
| Colorless amphibole | 10.4 | Ol, opx | Replacing ol (opx?), usually lining edges of replacement. |
| Opaques | 0.5 | Ol | Ilmenite, magnetite. Patches in areas replacing ol(?). |
| Hematite | 0.2 | Ol | Occurs with magnetite, colorless amphibole, and carbonate replacing ol(?). |

**COMMENTS:** Ilmenite near relict porphyroclasts. Magnetite associated with clear amphibole.
A few porphyroclasts preserve an igneous subophitic relationship between plag and cpx.
Modal percentages based on 591 point counts.

## THIN SECTION DESCRIPTION

**118-735B-7D-2 (Piece 1, 1-5 cm)**

**ROCK NAME:** Poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 8 | 1-5 | | Anhedral | Altered to talc/tremolite, smectite. Kinked, elongate crystals. |
| Plagioclase | 25 | 46 | 0.5-6.0 | | Anhedral | Partially altered to clay. Undulose extinction. Twinned crystals. |
| Clinopyroxene | 10 | 46 | 2-9 | | Anhedral | Interstitial between ol and plag crystals. Altered to amphibole + fine opaques. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | Dusty brown alteration of plag. Concentrated in zones. |
| Clays | 1 | Ol | Hematite stained smectite(?) after ol. |
| Chlorite | 1 | | Small interstitial patches in and around amphibole clots. |
| Actinolite | 35 | Cpx | Most of the amphibole is pale green to bluish green. Possibly actinolite/actinolitic hornblende. Completely replaces cpx on one half of the slide. This side of the slide is more intensely deformed, with a higher percentage of plag neoblasts. |
| Plagioclase | 19 | Plag | Neoblasts. Concentrated in amphibole-rich zones. |
| Talc | 2 | Ol | Clear fibrous aggregates on outside of ol pseudomorphs. |
| Tremolite | 3 | Ol | Clear, needle-like aggregates between ol and talc. |
| Hornblende | 1 | Cpx | Small patches of brown amphibole in cpx. |

**COMMENTS:** One half of slide is very amphibolitized. Most of the px is replaced. Ol occurs as large, anhedral grains. Point count predominately in less altered half of slide. Percentages based on 1665 point counts on the least altered section. Estimates above are for whole section.
Modal percentages: plagioclase 33.6; plagioclase neoblasts 10.8; cpx 14.1; ol 1.8; amphibole + spinel after cpx 28.5; talc/amphibole after ol 6.3; spinel after ol 0.1; vein-interstitial amphibole 3.6; other (mostly chlorite) 0.9.
Many px crystals have low birefringence. Probably optic axis orientation of cpx (not opx) crystals.

## THIN SECTION DESCRIPTION

**118-735B-8D-1 (Piece 5, 29-32 cm)**

**ROCK NAME:** Olivine metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Variable, 5 mm to 0.01 mm

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | 2 | 4 | 4.0-0.5 | | Irregular to slightly square | Porphyroclasts, 4 to 0.5 mm, fresh or partly smectized. |
| Plagioclase | 25 | 72 | 5.0-1.0 | | idiomorphic to elongate | Porphyroclasts. |
| Clinopyroxene | 7 | 18 | 0.5-4.0 | | Irregular, interstitial | Porphyroclasts, reaction rims with prehnite and tremolite. |
| Amphibole | Tr | 1 | 0.7-0.3 | | Irregular | Limpid, strongly pleochroic and replaced by colorless amphibole (mantled). |
| Orthopyroxene | | 5 | 0.5 | | Hexagonal, recrystallized | See secondary mineralogy. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol, opx | Smectite, pseudomorphs of cpx and partial replacement of olivine. |
| Actinolite | 5 | Px | Blue-green to light green, coronas around px. |
| Hornblende | 2 | Hbd, cpx | Brown to yellow brown. Replaces primary brown hbd and cpx |
| Plagioclase | 46 | Plag | Neoblasts, 0.01-0.08 mm, in matrix. |
| Clinopyroxene | 3 | Cpx | Neoblasts, 0.5 mm, mosaic with triple junctions. |
| Hematite | 1 | Cpx, ol, opx | Pseudomorphs of px mixed with clays, reaction product of ol. Other iron hydroxides replace opx. |
| Prehnite | 1 | Plag | Colorless to light green rim around plag. |
| Tremolite | 1 | | Fine needles in proximity of ol where plag reacted to prehnite. |
| Orthopyroxene | 5 | Opx? | Granoblasts forming mosaic, triple junctions. Highly stained by iron hydroxides. |

**COMMENTS:** One part of the thin section is undeformed and shows resorbed ol, hypidiomorphic and post-cumulus cpx. The deformed part of the thin section has porphyroclastic to mylonitic texture. Hydrous, low to medium grade metamorphism. Late replacement by smectite.

## THIN SECTION DESCRIPTION

**118-735B-8D-1 (Piece 7, 45-48 cm)**

**ROCK NAME:** Poorly foliated gabbro
**WHERE SAMPLED:**
**TEXTURE:** Subhedral, granular
**GRAIN SIZE:** Coarse
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 60 | 70 | 2.0-9.0 | | Subhedral—anhedral | Kinked, fractured, deformation twins. |
| Clinopyroxene | 10 | 25 | 2.0-8.0 | | Anhedral | Interstitial to plag, undulose, fractured. |
| Olivine? | | 5 | | | | Orange patches. Up to 5% may have been opx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 4 | Ol, opx | Fe-oxide stained smectite (?) at cores of ol/opx pseudomorphs. |
| Chlorite | 2 | | Along edges of amphibole patches. |
| Actinolite | 8 | Cpx, veins | Occurs as patches and as replacement on rims of cpx. Also in veins along fractures through plag and cpx. |
| Hornblende | 2 | Cpx | Brown to green patches in cpx. |
| Plagioclase | 3 | Plag | Neoblasts, 0.1mm, along grain boundaries. |
| Opaques | 3 | Ol, opx | Hematite/magnetite usually mixed with smectite in ol/opx pseudomorphs. |
| Talc | 3 | Ol, opx | Around ol/opx pseudomorphs. |
| Tremolite | 5 | Ol, px | Needle-like aggregates around ol/opx pseudomorphs. Structure is usually clay-opaque core, then actinolite, then talc zone which is sometimes patchy and sometimes continuous. |

**COMMENTS:** Large, Fe oxyhydroxides with dull reflectivity, associated with talc and tremolite. No foliation, only fracturing of cpx and plag and grain boundary recrystallization. Cpx with primary inclusions of plag and possibly ol.

## THIN SECTION DESCRIPTION

**118-735B-9D-1 (Piece 3, 14-17 cm)**

**ROCK NAME:** Porphyritic foliated metagabbro
**WHERE SAMPLED:**
**TEXTURE:** Hypidiomorphic, slightly porphyroclastic
**GRAIN SIZE:**
**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | - | Tr | 0.2 | | Irregular | Replaced by mixture of carbonate, Fe hydroxide, and tremolite. |
| Plagioclase | 35 | 40 | 0.5-1.5 | | Prismatic | Generally well-preserved with marginal replacement by prehnite and deformation into granoblasts. |
| Clinopyroxene | - | 58 | 0.08-1.3 | | Rounded to hypidiomorphic | All replaced by green amphiboles (post-cumulus phase). |
| Orthopyroxene? | - | 2 | 0.4 | | Irregular | Replaced by a mixture of tremolite and Fe hydroxide. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol, opx | Replacing ol and opx. |
| Tremolite | 2 | Px | Intimately associated as replacement products of opx along with iron hydroxides. |
| Hornblende | 57 | Cpx veinlets | Pale yellow to pale green pseudomorphs of cpx. Same grain size. |
| Plagioclase | 4 | Plag | Neoblasts, 0.02-0.06 mm. |
| Amphibole | Tr | Plag | Replacing cpx and initial brown amphibole. |
| Prehnite | 1 | Plag | Light green. Replaces rims of plag. |
| Iron hydroxides | 1 | Opx, ol | Replacement product of opx and/or ol. Both magnetite and Fe oxyhydroxides present in smectites. |

**COMMENTS:** Suggested crystallization order ol-plag-cpx-opx? Slight high temperature deformation and recrystallization. Medium grade hydrous metamorphism (no chlorite), late vein filling (green amphibole).

## THIN SECTION DESCRIPTION

**118-735B-9D-1 (Piece 23, 120-122 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 48 | 1.0-6.0 | | Flattened | Porphyroclasts; bent and twinned. |
| Clinopyroxene | 14 | 45 | 1.0-4.0 | | Anhedral | Porphyroclasts, brown hornblende and neoblast margins. |
| Olivine | 1 | 7 | 0.5-2.0 | | Elongate | Porphyroclasts replaced by hematite, calcite and smectite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Smectite mixed with hematite after opx(?). |
| Carbonate | Tr | Ol | In opx pseudomorphs. |
| Actinolite | Tr | Fills veins, replaces neoblasts | Pale green, post-deformational. |
| Hornblende | Tr | Cpx | Red-brown lamellae and margins of cpx, also neoblasts. |
| Plagioclase | 18 | Plag | Neoblasts and crushed grains. |
| Clinopyroxene | 14 | Cpx | Neoblasts. |
| Olivine | 2 | Ol | Neoblasts(?) or crushed grains. |
| Hornblende | 15 | Cpx(?) fractures | Green-brown, fills fractures in plag, syn-deformational? |
| Opaques | 2 | | Bands in mylonitic zones. |
| Hematite | 2 | Ol | Ol pseudomorphs. |

**COMMENTS:** Abundant intergrowths of reddish brown hornblende and secondary pyroxene. Little post-deformational alteration. Contains primary ol but no primary opx.

## THIN SECTION DESCRIPTION

**118-735B-10D-1 (Piece 6A, 24-26 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Very fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 10 | 0.2-0.3 | | Anhedral | Kinked fragments in elongate aggregates. |
| Plagioclase | 8 | 45 | 0.4-3.0 | | Anhedral | Elongate, undulose porphyroclasts. |
| Clinopyroxene | 8 | 45 | 0.4-2.0 | | Anhedral | Kinked, undulose - in aggregates with smaller fragments and neoblasts, partially altered to amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Orange tint in ol fractures and surfaces. |
| Actinolite | 2 | Cpx | At edges of very thin cpx-amph zones. |
| Hornblende | 15 | Cpx, veins | Green to brown, replacing cpx in deformed clasts and veins cutting foliation. |
| Plagioclase | 37 | Plag | Mosaic, sutured neoblasts 0.1-0.5 mm. |
| Opaques | 1 | Cpx | In cpx altered clasts; black, very fine, probably magnetite or ilmenite. |
| Opaques | 5 | Ol, cpx | Dark red to red-black, in granular aggregates after ol. Commonly very elongate in plane of foliation. |
| Clinopyroxene | 1 | Cpx | Small, subrounded neoblasts and clasts, 0.05-0.2 mm. Some are individual grains in matrix, others in cpx porphyroclasts. Larger grains may be undulose and kinked; likely to be fragments rather than neoblasts. |

**COMMENTS:** Foliation defined by elongate plag and stringers of altered and fragmented mafic minerals. These stringers can have aspect ratios of 1:30 to 1:40 (width to length).

## THIN SECTION DESCRIPTION

**118-735B-10D-1 (Piece 8, 46-49 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic to porphyroclastic

**GRAIN SIZE:** Very fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 5 | — | | | Small disaggregated remnant ol fragments. |
| Plagioclase | 2 | 55 | 0.05 | | Elongate, anhedral | Very rare unrecrystallized grains. |
| Clinopyroxene | 10 | 40 | 0.5-0.7 | | Anhedral | Partially altered porphyroclasts, bent and kinked in some places. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol, cpx | Clay-tremolite clots with hematite staining in ol pseudomorphs(?) |
| Actinolite | 1 | Amph | Late stage on rims of cpx-amph clots. |
| Hornblende | 10 | Cpx | Green, between cpx clasts and neoblasts. Gradation from brown amph. |
| Plagioclase | 50 | Plag | Neoblasts, mostly less than 0.03 mm. |
| Opaques | 1 | Cpx | Magnetite around cpx neoblasts and in grain boundaries on cpx clots. |
| Hematite | 2 | Ol | In ol pseudomorphs as large grains and disseminated in magnetite-hematite-cpx clumps. |
| Hornblende | 1 | Cpx | Brown; rims and patches in cpx. |
| Clinopyroxene | 19 | Cpx | 0.05 to 0.2 mm grains. Broken aggregates and recrystallized grains. |

**COMMENTS:** Protolith was an ol-bearing gabbro; no evidence opx in mylonitic zones. Cpx and ol string out in long bands or completely disaggregated. Foliation defined by these stringers and by elongate plag. Foliation is bent or folded in section.

## THIN SECTION DESCRIPTION

**118-735B-10D-1 (Piece 12A, 64-68 cm)**

**ROCK NAME:** Altered mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic, porphyroclastic

**GRAIN SIZE:** Fine to rare coarse grains

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | 1 | 0.2 | | Subrounded | Identification uncertain. |
| Plagioclase | 3 | 43 | 0.2-1.0 | | Anhedral | Undulose shards. |
| Clinopyroxene | 5 | 54 | 0.5-1.0 | | Anhedral | Subhedral, largely altered to clays, amph. |
| Orthopyroxene | 1 | 2 | 1.0 | | Anhedral | Elongate, parallel to foliation. Some cpx exsolution. Largely altered to opaque assemblage. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Cpx, plag | Fine brown to green patches in cpx cores. A little on plag boundaries and fractures. |
| Carbonate | 1 | Vein, ol? | 0.2 mm wide vein, parallel foliation, needles growing parallel to wall of vein, probably aragonite. |
| Actinolite | 2(?) | Cpx, veins | Some pale green, fibrous vein-fill exists, possibly actinolite. |
| Hornblende | 5 | Cpx | Green to brown. After cpx, particularly along veins. |
| Plagioclase | 35 | Plag | 0.02 to 0.3 mm sutured, mosaic neoblasts. |
| Opaques | 15 | Cpx, opx | Anhedral network between cpx grains. |
| Hematite | 5 | Cpx | Mixed with cpx clots and intergranular opaques. |
| Clinopyroxene | 18 | Cpx | Small grains. Neoblasts around larger cpx, 0.1–0.2 mm. Both recrystallized and granulated fragments. |

**COMMENTS:** Well-developed foliation defined by mylonitic plag lenses, 4–6 mm long, with interlayered mafic lenses and stringers of cpx fragments, amph and opaques. White veins are carbonate, probably aragonite. Opaques mostly between mafic grains—relatively rare in plag sections and fill vertical fractures.

## THIN SECTION DESCRIPTION

**118-735B-10D-2 (Piece 2, 18-20 cm)**

**ROCK NAME:** Porphyroclastic olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 45 | 9 | 2.0-4.0 | | Anhedral | Kink bands. |
| Plagioclase | 19.8 | 45 | 1.0-5.0 | | Anhedral | |
| Clinopyroxene | 27.9 | 46 | 3.0-15.0 | | Anhedral | Some oikocrysts enclosing plag. |
| Orthopyroxene | 0.4 | 0.4 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Orthopyroxene | Tr | Ol | |
| Olivine | 0.5 | Ol | Neoblasts, <0.2 mm in size. |
| Plagioclase | 24.6 | Plag | Neoblasts, <0.2 mm in size. |
| Clinopyroxene | 7.8 | Cpx | Neoblasts, <0.2 mm in size. |
| Chlorite | Tr? | | |
| Tremolite | 2.1 | Ol | Colorless to pale green. |
| Hornblende | 10.3 | Cpx | Brown to green amphibole replacing cpx. |
| Opaques | 1.3 | Ol, cpx | |
| Hematite | 0.8 | Ol | |

**COMMENTS:** Poorly foliated with localized mylonitic zones and augens of plag and ol. Some relict ophitic/subophitic textures. Percentages based on 1500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-11D-1 (Piece 1, 6-8 cm)**

**ROCK NAME:** Mylonitic to porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic with mylonitic zones

**GRAIN SIZE:** Very fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | ? | 0.3 | | Subrounded | Disaggregated grains in mylonitic matrix. |
| Plagioclase | 10 | 40 | 0.1-5.1 | | Anhedral | Elongate, undulose grains surrounded by mosaic neoblasts. |
| Clinopyroxene | 25 | 50 | 0.1-2.0 | | Anhedral | Large porphyroclasts with smaller cpx around them. Fine recrystallized zones at boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | | in fractures and boundaries. Perhaps minor actinolite as well. |
| Hornblende | 51 | Cpx, veins | Brown to dark green. Small patches in cpx and in veins parallel to foliation. |
| Plagioclase | 25 | Plag | Anhedral sutured aggregates, 0.01 to 0.1mm. |
| Opaques | 15 | Grain boundaries | Anhedral network at grain boundaries, consisting mostly of cpx clots. Also in veins, but largely absent from plag-rich lenses. |
| Clinopyroxene | 20 | Cpx | 0.02 to 0.2mm, angular to subrounded. Small grains in aggregates are clearly recrystallized, larger ones occur around porphyroclasts and singly in matrix. |

**COMMENTS:** Protolith definitely ol-bearing. Hard to estimate proportions and whether opaques may have been primary. Foliation defined by plag lenses. Opaques mostly grey-white in reflected light; probably ilmenite with exsolution of magnetite.

## THIN SECTION DESCRIPTION

**118-735B-12R-1 (Piece 5A, 32-43 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | 50 | | | | Few bent pieces, crushed. |
| Clinopyroxene | 20 | 50 | | | | |
| Ilmenite | ? | ? | | | | Mostly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 3 | Cpx, hbd | Late, static (?). |
| Hornblende | 3 | Cpx | Neoblasts. |
| Plagioclase | 35 | Plag | Some neoblasts, others crushed. |
| Clinopyroxene | 21 | Cpx | Neoblasts. |
| Ilmenite | 3 | Cpx | Appears as exsolved rods in cpx partially replaced by hematite, intergrown with cpx neoblasts and in massive clots on tails of cpx augen. Cannot distinguish primary from secondary ilmenite. |

## THIN SECTION DESCRIPTION

**118-735B-12R-1 (Piece 1, 65-68 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 50 | — | — | Ovoid | Porphyroclasts. |
| Clinopyroxene | 8 | 50 | — | — | Flattened | Porphyroclasts. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 31 | Cpx | Brown and green. Sector-zoned. Also in vein. |
| Plagioclase | 59 | Plag | Neoblasts. |
| Clinopyroxene | 10 | Cpx | Neoblasts. |
| Hematite | 1 | Cpx | In hbd vein. |

**COMMENTS:** Section is crosscut by hbd vein which is 0.5–0.2 cm wide. Vein hbd is coarse, 1–2 mm across. Porphyroclasts of cpx are replaced by some hbd. Veins postdate deformation.

## THIN SECTION DESCRIPTION

**118-735B-12R-2 (Piece 5, 36-38 cm)**

**ROCK NAME:** Porphyroclastic olivine metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 15 | 0.1-3 | | Anhedral | Elongate eyes and grains in matrix. |
| Plagioclase | 10 | 70 | 0.1-1 | | Anhedral | Elongate, undulose porphyroclasts |
| Clinopyroxene | 5 | 12 | 0.2-1 | | Anhedral | Single small grains off large clasts, sheared, elongate grains |
| Orthopyroxene | 2 | 3 | 0.2-1 | | Subhedral | A few small grains in sheared zones. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol, plag | Dusty in plag, a little smectite after ol pseudomorphs. |
| Epidote | 3 | | Euhedral laths in plag mosaic, second to third order colors. Odd clinozoisite. |
| Actinolite | 4 | Cpx | Pale green veins. May include an actinolitic hbd. |
| Hornblende | 43 | Cpx | Brown patches in primary cpx. |
| Plagioclase | 58 | Plag | 0.03–0.20 mm mosaic of neoblasts. |
| Opaques | 2 | Ol | Mostly after ol, some in groundmass, some in cpx. |
| Talc | 2 | Ol | Replacing ol lenses. |
| Tremolite | 2 | Ol | Replacing ol lenses, aggregates of needle-like grains. |

## THIN SECTION DESCRIPTION

**118-735B-12R-3 (Piece 1A, 8-10 cm)**

**ROCK NAME:** Troctolite

**WHERE SAMPLED:**

**TEXTURE:** Pophyroclastic

**GRAIN SIZE:** —

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | 18 | 29 | 1-4 | | Euhedral-subhedral | Altered into tremolite (or actinolite) + talk + opague locally rimmed by brown hbd whow wavy extinction, kink bands recrystallization. |
| Plagioclase | 41 | 65 | 1-5 | | Anhedral | Porphyroclasts. |
| Clinopyroxene | 3 | 6 | 0.5-2 | | Anhedral | Replaced by green and brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Ol | Replacing ol along veins, color brown along amphibole vein between talc and plag. Colorless and pale green. |
| Actinolite | 5 | Ol, cpx | Replacing ol and cpx from the rim. |
| Hornblende | <1 | Ol, cpx | Replacing ol and cpx. |
| Plagioclase | 24 | Plag | Neoblasts, 0.5 mm to a few mm, irregular grain shape |
| Talc | 5 | Ol | Replacing ol, surrounding tremolite replacing ol. |
| Hornblende | 3 | Cpx | Vein cutting nearly perpendicular and filling cracks in plag; also replacing cpx |
| Fe-Ti oxide | Tr | Ol | Accompanying actionolite-tremolite and replacing ol. |

**COMMENTS:** Primary minerals were obtained by point counting (total 2000 counts). Ol is deformed and poorly recrystallized into smaller grains, but restored shape shows it was euhedral. Ol shows performed orientation which is subparallel to the foliation due to deformation.

## THIN SECTION DESCRIPTION

**118-735B-12R-2E (Piece 3, 48-55 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral, granular

**GRAIN SIZE:** very coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10.5 | 16.0 | 4.20 | | Anhedral | Some what fractured. Talc/tremolite alteration. |
| Plagioclase | 46 | 55 | 8.22 | | Anhedral | Extensive alteration to brown green cpx. |
| Clinopyroxene | 13.9 | 28 | 6.20 | | Anhedral | Some brittle fracture detormations twins – grain boundary, recrystallization of some clay. |
| Orthopyroxene | Tr | 1 | 0.2 | | Anhedral | Small rims around a couple, altered ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clay | 2 | Plag | Fine dusting in plagiclase. paricularly around ol replacements and in fractures crosscutting 1 cpx, and some ol. |
| Chlorite | 0.3 | Ol, cpx | Mixed with ol rims. |
| Actinolite | 13.5 | Cpx | Light green to green amphibole, patches and needles after cpx. Also filling fractures in plag and some intergranular spaces. |
| Hornblende | 0.5 | Cpx | Patches of brown amphibole replacing cpx and in alteration areas of ol. |
| Plagioclase | 7.8 | Plag | Small grains (<0.1 mm), both primary and neoblasts. |
| Tremolite | 3.1 | Ol | Alteration needles around weathered ol. |
| Talc | 1 | Ol | Patchy alteration usually around outside of ol pseudomorphs. |
| Opaques | 1 | Ol, cpx | Magnetite in ol pseudos, rarely in and along margins of cpx ol counted as ol. |

**COMMENTS:** Percentages based on 3375 point counts. Altered (?) fractures in ol counted as ol. Rock is heterogenous because of size. Rarely some 0.2-0.5 mm "graphic " type amphibloe-plag intergrowths probably after interstital cpx-plag intergrowths.

## THIN SECTION DESCRIPTION

**118-735B-12R3-2F (Piece 2F, 83-85 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Very coarse grained

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Plagioclase | 75 | 80 | 3-20 | | Anhedral |
| Clinopyroxene | 17 | 20 | 7-8 | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 4 | Plag | Neoblasts. |
| Amphibole | 4 | Cpx, amphibole | Partial replacement of cpx by green and brown amphibole along rims, green amphibole in fractures across plag. |

**COMMENTS:** Primary igneous texture of interlocking crystals is well preserved.
Oriented thin section, cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118-735B-13R-1 (Piece 11B, 102-105 cm)**

**ROCK NAME:** Porphyroclastic olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic to mylonitic

**GRAIN SIZE:** Coarse to very fine

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 14 | 0.5-3 | | Anhedral | Elongate fractured eyes. |
| Plagioclase | 20 | 50 | 0.5-4 | | Anhedral | Undulose, fractured, elongate porphyroclasts. |
| Clinopyroxene | 15 | 36 | 1-8 | | Anhedral | Large, slightly bent grains with some amphibole replacement, and smaller fragments of large grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clay | <1 | Plag | Light dusting in clear plag. |
| Clays | 2 | Ol | Dark green smectite fractures in ol. |
| Chlorite | 2 | | Small patches in amphibole clots around cpx and ol. |
| Actinolite | 10 | | Clear patches in and rims on cpx. Fine fibrous aggregates in sheared zones. Also filling fractures. |
| Hornblende | 2 | Cpx | Brown patches in cpx ≈ 0.1 mm. |
| Plagioclse | 31 | Plag | Very fine grains to neoblasts in mylonitic bands. |
| Opaque | 1 | Ol | Fine aggregates with tremolite-talc zones around ol. |
| Tremolite | 4 | Ol, cpx | Fibrous aggregates around mafic phases, usually ol. |
| Talc | 3 | Ol | Patchy replacement near ol. |

**COMMENTS:** Oriented thin section, cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118-735B-13R-1 (Piece 17, 148-158 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic

**GRAIN SIZE:** Fine to very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3 | 1-2 | | Anhedral | Totally replaced by Fe oxide + clay and colorless amphibole. |
| Plagioclase | 45 | 90 | 2-12 | | Anhedral | Intense mechanical twins. |
| Clinopyroxene | 5 | 7 | 4-6 | | Anhedral | Replaced by amphibole along rims. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clay | 1 | Ol | Mixed, with Fe oxide replacing ol. |
| Chlorite | <1 | Ol | |
| Plagioclase | 40 | Plag | Neoblasts. |
| Brown amphibole | 1 | | |
| Colorless amphibole | 2 | | |
| Green amphibole | 5 | Cpx, plag | Replaces cpx at rims and filling fractures crosscutting plag. |

**COMMENTS:** Small thin section of coarse grained unit. i.e., model estimate unrealistic.

## THIN SECTION DESCRIPTION

**118-735B-13R-2 (Piece 4B, 55-58 cm)**

**ROCK NAME:** Porphyroclastic olivine metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 6.2 | 2-5 | | | Kink banding and recrystallization of large ol crystal |
| Plagioclase | 41.0 | 69.9 | | | | Porphyroclasts, stretched in places |
| Clinopyroxene | 18.9 | 23.7 | 2- 10 | | | Porphyroclasts. |
| Hornblende | 0.2 | 0.2 | 0.5 | | | Blebs in cpx and in interstitial areas |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 2.4 | Ol, plag | In coronas around tremolite, replacing ol. |
| Tremolite | 2.6 | Ol | In coronas around ol. |
| Hornblende | 4.4 | Cpx,<br>veins | Veins oblique to foliation |
| Plagiclase | 27.3 | Plag | Neoblasts. Recrystallization at grain boundaries. |
| Clinopyroxene | 0.6 | Cpx | Neoblasts. Recrystallization at grain boundaries. |
| Talc | 0.3 | Ol | In coronas with tremolite. |
| Opaques | 0.1 | Ol | |
| Amphibole | 0.1 | Plag | |

**COMMENTS:** Percentages based on 2000 point counts. Cpx shows recrystallization of primary grains. Showing exsolution to homogeneous cpx. Brown amphibole typically associated with this recrystallization. Reaction rims around ol show that tremolite grows radially from contact into the ol while chlorite forms outer rings on the tremolite and grows outward away from the ol. Magnetite lines the inner boundary between the unaltered ol and the tremolite.

## THIN SECTION DESCRIPTION

**118-735B-13R-2 (Piece 4c, 60-63 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 7 | 0.2-2.0 | | Anhedral | Elongate, granular aggregates with kink bands. |
| Plagioclase | 15 | 55 | 0.2-4.0 | | Anhedral | Elongate, very subrounded undulose porphyroclasts. |
| Clinopyroxene | 15 | 38 | 0.5-2.0 | | Anhedral | Enclose plag. 20-80% replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | Dusty grains on plag grain boundaries. |
| Chlorite | 2 | Cpx, ol | With fibrous amphibole patches. |
| Actinolite | 18 | Cpx, ol | Fibrous, pale green amphibole surrounding outside of cpx and ol pseudomorphs, probably includes actinolitic hbd. Also fills veins and fractures in plag. |
| Hornblende | 2 | Cpx | Brown and dark green amphibole patches in cpx. |
| Plagioclase | 38 | Plag | Neoblasts, most 0.05-0.10 mm. Clots of smaller grains. |
| Opaque | 1 | Ol | Fine aggregates in ol pseudomorphs. |
| Tremolite | 3 | Ol | Clear amphibole in ol pseudomorphs. |
| Talc | 1 | Ol | Clear patches in ol pseudomorphs. |

**COMMENTS:** Foliation more neatly developed in many other samples. No mylonite zones at all. Intense deformation.

## THIN SECTION DESCRIPTION

**118-735B-14R-1 (Piece 2B, 35-38 cm)**

**ROCK NAME:** Mylonitic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine, heterogranular 0.1 mm to 1 cm

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | Tr | | | Lensoid | Interpreted-from intergrowths of magnetite, tremolite and clays. |
| Plagioclase | 4 | 58 | 0.4-1.6 | | Elongated | Porphyroclast rarely observed; transformed into neoblasts. |
| Clinopyroxene | 10 | 35 | 0.6-10 | | Rounded, elongated | Large porphyroclasts with pressure shadows of neoblasts and amphiboles. |
| Ilmenite | 1 | 2 | | | Irregular | Along foliation planes, intergrown with tremolite, brown amphibole. |
| Orthopyroxene | 3 | 5? | 0.1-0.4 | | | Small porphyroclasts, rotated in foliation planes. Replaced by green amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | See ol interpretation. |
| Tremolitic actinolite | 5 | | Fibrous, as veins or rims amphibole pseudomorphs after cpx, opx. Cleavages not preserved. |
| Hornblende | 13 | Cpx | Green to very light brown. Pseudomorphs after cpx. |
| Plagioclase | 54 | | Neoblasts, 0.02-0.50 mm. Form bands up to 5 mm thick around porphyroclasts. |
| Clinopyroxene | 5 | Cpx | Neoblasts, 0.02-0.30 mm distributed around cpx porphyroclasts. |
| Brown amphibole | 2 | Cpx | Associated with intergrown ilmenite and magnetite, in foliation planes and cpx neoblasts and fractures which cut the foliation. |
| Blue-green amphibole | 2 | | |
| Magnetite | 1 | Tremolite, opx | Very fine grains, <0.05 mm. Reaction products associated with amphiboles. |
| Chlorite | Tr | | Bluish interference colors, intergrown with plag neoblasts. |

**COMMENTS:** This rock was intensely plastically deformed. Cpx is strained and recrystallized. Almost all plag is recrystallized. Three stages of amphible formation: brown → green, green-brown → blue green. Mysterious phase is present in trace amounts, probably epidote-type mineral.

## THIN SECTION DESCRIPTION

**118-735B-14R-3 (Piece 2A, 31-35 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Foliated, cut by vein

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | — | 5 | 3.0 | | Elongate | Pseudomorphed by calcite, hematite. |
| Plagioclase | 12 | 50 | 1.0–3.0 | | Flattened | Porphyroclasts. |
| Clinopyroxene | 5 | 45 | 5.0–20.0 | | Lensoid | Replaced by green and brown hbd, mechanical twins. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Ol | In ol pseudomorphs. |
| Chlorite | 1 | Cpx, plag | Lenses. |
| Actinolite | 5 | Ol, cpx | Static replacement of ol and cpx porphyroclasts. |
| Hornblende | 30 | Cpx | Green-brown in large vein, replacement, syn- and post-deformational. |
| Plagioclase | 37 | Plag | Neoblasts. |
| Hematite | Tr | Ol | In ol pseudomorphs. |
| Clinopyroxene | 10 | Cpx | Neoblasts. |

**COMMENTS:** Gabbro was deformed in amphibolite facies, syndeformational green and brown hbd intergrown with cpx neoblasts. Coarse euhedral crystals in hbd vein appear to resorb(?) adjacent amphiboles. Vein is approximately 1 cm wide.

## THIN SECTION DESCRIPTION

**118-735B-14R-3 (Piece 10, 136-141 cm)**

**ROCK NAME:**

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Originally coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | — | 1 | 0.5 | | | |
| Plagioclase | 40 | | ≤1.2 cm | | | Large porphyroclasts, strained, recrystallized |
| Clinopyroxene | 15 | | ≤2.0 cm | | | Kinked, bent crystals. |
| Orthopyroxene | 5 | | ≤1.0 cm | | | |
| Amphibole | Tr | 1 | 0.1 | | Irregular | Blebs, limpid, clear along cpx cleavages. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Opx | Pale yellow green, replacing along cleavages. |
| Clays | Tr | Ol | Brown to yellow, forming mesh-like texture in lense-shaped pseudomorphs with magnetite. |
| | | | Forming 0.4 mm px crystals. |
| Tremolite | 8 | Opx, cpx | Fibrous, colorless, up to 0.4 mm in width. Cutting px crystals. Fringe pseudomorphs after ol |
| Hornblende | 5 | Fractures | In fractures cutting plag and rimming or pseudomorphing px crystals. |
| Plagioclase | 20 | Plag | Very small neoblasts, 0.01-0.30 mm. |
| Clinopyroxene | 5 | Primary cpx | Granoblasts around cpx up to 0.4 mm in size. Twins still present. |
| Amphibole | 1 | Cpx | Intimately associated with granoblasts. |
| Magnetite | Tr | Ol? | See clays, granules less than 0.02 mm. |
| Talc | Tr | Veinlet | Width 0.03-0.05 mm, cutting opx. |

**COMMENTS:** High temperature plastic deformation of silicates (anhydrous); neoblasts, amphiboles and tremolite/actinolite. Restoration of primary proportions complicated by deformation and recrystallization.

## THIN SECTION DESCRIPTION

**118-735B-14R-4 (Piece 2, 22-25 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulus, recrystallized into granoblastic

**GRAIN SIZE:**

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | 5 | 6 | ≤3.0 | | Irregular | Ameboidal interstitial grains, kinks. Margins replaced by talc and magnetite. |
| Plagioclase | 20 | 78 | 1.0-3.5 | | | Porphyroclasts, strained (deformed twin planes), recrystallized into neoblasts. |
| Clinopyroxene | 7 | 15 | 0.5-3.5 | | | Rimmed by green amphibole. Exsolution lamellae of opx |
| Spinel | Tr | Tr | 0.05 | Chromite | Euhedral | Included in or attached to ol. Possibly secondary |
| Brown amphibole | 1 | 1 | 0.02-0.3 | | Blebs | Brown, limpid, crystals included in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 2 | Cpx fractures | Green, replace cpx and open fractures and primary amphiboles. Some brown and some colorless amphibole. |
| Plagioclase | 56 | Plag | Granoblasts, polygonal, abundant triple junctions, 0.04-0.40 mm. |
| Talc | 1 | Ol | Blades (<0.1 mm) rimming ol, associated with ol. |
| Prehnite | 2 | Plag | Light green. Fibrous, thin rims (0.02-0.25 mm). |
| Clinopyroxene | 5 | Cpx | Granoblasts (0.03-0.2 mm), polygonal, grains intergrown with colorless amphiboles |

**COMMENTS:** Ol rimmed by alteration phases: oxides, talc, and green fibrous amphibole. Cpx is replaced by greenish (late) amphibole rims and by brown amphibole in patches, particularly concentrated at rims and in areas of recrystallization. Primary cpx contains exsolution of opx and amphibole replacement along lamellae. Cpx is partially recrystallized to a homogeneous cpx with inclusions of opx and amphibole which sill maintain a roughly parallel orientation to original exsolution. Amphibole is very early (not associated with deformation), syn- to post-exsolution in cpx.

## THIN SECTION DESCRIPTION

**118-735B-14R-2 (Piece 1A, 22-25 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Gneissic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 5 | 0.2–0.4 | | Anhedral | Relict inside cpx neoblasts(?). |
| Plagioclase | — | 50 | | | | Completely recrystallized. |
| Clinopyroxene | 15 | 43 | 1.0–2.0 | | Rounded | Porphyroclasts. |
| Ilmenite | 2 | 2 | | | | Difficult to determine if primary or secondary; probably mostly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 2 | Ol | Tremolite, also in late veins. |
| Hornblende | 15 | Cpx | Brown to red, some could be primary. |
| Plagioclase | 50 | Plag | Neoblasts. |
| Clinopyroxene | 13 | Cpx | Neoblasts. |

**COMMENTS:** Very high temperature crystallization. Smaller neoblasts may be ol. Other ol-rich areas are statically replaced by tremolite. Plag appears to have been crushed, then recrystallized.

## THIN SECTION DESCRIPTION

**118-735B-15R-1 (Piece 7B, 90-93 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoporphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 25 | 80 | 1.0–6.0 | | | Highly strained and recrystallized into granoblasts. |
| Clinopyroxene | — | 19 | 0.5–7.0 | | | All recrystallized. |
| Ilmenite | — | 1 | 0.2 | | | Included in brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Plag, amph | Blue to gray interference colors, lamellae, replaces light green-brown amphibole. |
| Tremolite | 1 | Amph | Locally replaces light green-brown amph, but pre-dates blue-green amph rimming, fibrous. |
| Hornblende | 9 | Pyroxene | Light green-brown pseudomorphs after cpx. Kinking post-dates amphibole formation. Replaces brown amphibole. |
| Plagioclase | 55 | Plag | Granoblasts, crushing of larger plag, 0.02–0.2 mm, then partially chloritized. |
| Amphibole | 8 | Pyroxene | Dark brown to yellow brown (strong pleochroism), idioblastic. |
| Magnetite | 1 | Ilmenite? | Idioblastic, 0.02–0.2 mm, closely associated with brown amphibole (Ti-bearing opaque?). |
| Zoisite(?) | Tr | | High relief mineral, second order birefringence. Contains rounded inclusion of chlorite and amphibole. |

**COMMENTS:** Deformation of plagioclase.

Amphibole history:

1) Cpx replaced by brown amphibole.
2) Green amphibole.
3) Amphiboles are deformed (kinked).
4) Tremolite (chlorite?).
5) Blue-green amphibole.

## THIN SECTION DESCRIPTION

**118-735B-15R-2 (Piece 17A, 128-130 cm)**

**ROCK NAME:** Mylonitic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Less than 1.7 mm

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 73 | <0.4 | | | Porphyroclasts, highly strained and surrounded by neoblasts. |
| Clinopyroxene | Tr | 25 | <3.0 | | | Porphyroclasts, almost completely replaced by green amphiboles. |
| Orthopyroxene | Tr | 2 | <1.5 | | | Completely replaced by assemblage of tremolite and magnetite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite | 2 | Opx, ol(?) | Lenses, intergrowth of magnetite. |
| Hornblende | 23 | Cpx | Green hornblende pseudomorphs after pyroxenes or in lenses parallel to the foliation, fibers 0.03 mm thick. |
| Plagioclase | 68 | Plag | Neoblasts, <0.2 mm in size. |
| Magnetite | 2 | Opx, cpx | Disseminated as minute grains along deformation planes. |

**COMMENTS:** Plag is highly recrystallized. Px is recrystallized under medium grade conditions (post-mylonitization).

## THIN SECTION DESCRIPTION

**118-735B-15R-3 (Piece 8, 92-96 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic, granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.6 | 6 | 1.0-4.0 | | Anhedral | Altered to a network of crosscutting clay-filled fractures or patches of colorless amphibole or talc and magnetite. Rimmed by green amphibole. |
| Plagioclase | 23.5 | 50 | 5.0-10.0 | | Anhedral | Near veins altered to albite. |
| Clinopyroxene | 19.8 | 44 | 2.0-10.0 | | Anhedral | Replaced by brown and green amphibole. Some plastic deformation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.3 | Ol, vein | Replacing ol, in vein and fractures cross-cutting plag. |
| Chlorite | 0.1 | Ol | |
| Plagioclase | 22.9 | Plag | Neoblasts, near green amphibole veins plag probably albite. |
| Magnetite | 2.4 | Ol | |
| Amphibole | 6.5 | Cpx | Brown. Occurs as patchy replacement in cpx. |
| Amphibole | 19.2 | Cpx | Green. In veins with albite. |
| Amphibole | 2.1 | Ol | Colorless. Probably tremolite. |
| Talc | 1.1 | Ol | |

**COMMENTS:** Modal proportions vary as a function of proximity to veins: away from veins cpx approx 25% of total and green amphibole ≈ 11%, near veins cpx drops to approximately 12% and green amphibole increases to approximately 32%. Primary igneous textures relatively well preserved. Ol often wrapped around or partially included in cpx.

## THIN SECTION DESCRIPTION

**118-735B-16R-3 (Piece 4B, 44-46 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 40 | 0.7-1.6 | | | Porphyroclasts highly strained, kinked and recrystallized. |
| Clinopyroxene | 20 | 50 | 0.4-3.0 | | | Porphyroclasts largely replaced by pale green to light brown amphibole. |
| Orthopyroxene | 2 | 10 | 0.5-1.0 | | | Porphyroclasts largely replaced by green amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite | 8 | Px | Very minute interlocking needles, but general outline of px still preserved. |
| Hornblende | 24 | Px | Green to light green-yellow, more colored when replacing opx, some pale brown amphibole replaces cpx. |
| Plagioclase | 30 | Plag | Neoblasts, <0.7 mm, in size, in the matrix. |
| Amphibole | 5 | Amphibole | Blue-green, late-stage fibrous amphibole fringing other amphiboles. |
| Magnetite | 1 | | Fine-grained, associated with green amphiboles and marginal brown amphibole. |

**COMMENTS:** This rock more is relatively more mafic. Protolith of gabbronoritic composition (according to secondary mineral assemblages), but without significant ilmenite content. Intermediate stage of amphibole replacement since relicts of all phases are observed.

## THIN SECTION DESCRIPTION

**118-735B-16R-4 (Piece 5, 77-79 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulus

**GRAIN SIZE:**

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 35 | 45 | <3.6 | | Euhedral, deformed | First cumulus phase enclosed in cpx where rock undisturbed. |
| Clinopyroxene | 15 | 55 | <8.0 | | | Large poikilitic phenocrysts. |
| Spinel | Tr | Tr | | | Euhedral | Inclusion in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 36 | Cpx | Pale yellow brown pseudomorphs after cpx. Locally form symplectite-like intergrowths. |
| Plagioclase | 10 | Plag | Granoblasts, <1.0 mm, formed by crushing of larger plag. |
| Amphibole | 1 | Cpx | Light green, rims around amphibole pseudomorphs and open fractures in plag. |
| Amphibole | 3 | Cpx | Found at outer margins of cpx but inside light green amphibole where it is present. This relationship is clearly visible in undeformed, large cpx. |

**COMMENTS:** Inhomogeneously formed gabbro, recrystallized into medium grade metamorphism. Formation of green amphibole postdates the formation of pale brown and pale yellow-brown amphibole. Originally cumulate gabbro with crystallization order plag to cpx.

## THIN SECTION DESCRIPTION

**118-735B-16R-5 (Piece 1B, 24-26 cm)**

**ROCK NAME:** Meta-microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Weakly foliated

**GRAIN SIZE:** Fine to medium

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 16 | 0.2–1.0 | | Anhedral | Relicts concentrated on one end of the slide show kink banding. |
| Plagioclase | 40 | 50 | 0.02–1.0 | | Anhedral | |
| Clinopyroxene | 25 | 34 | 0.2–1.0 | | Anhedral | Crystals pinch out. Cross hatch twins. Recrystallized. Indicates minor deformation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Ol, plag | In reaction coronas around ol pseudomorphs which are filled with tremolite and/or talc (both occur). |
| Tremolite/ actinolite | 4 | Ol, veins | Veins are oblique to weak foliation. |
| Hornblende | 2 | Cpx, veins | Green. |
| Hornblende | 2 | Cpx | Brown. At grain boundaries, intergrown with cpx neoblasts. |
| Plagioclase | 10 | Plag | Neoblasts. |
| Talc | 10 | Ol | |
| Clinopyroxene | 5 | Cpx | Neoblasts. |

**COMMENTS:** Replacements are largely static with deformation limited to grain boundaries.

## THIN SECTION DESCRIPTION

**118-735B-16R-5 (Piece 2A, 47-51 cm)**

**ROCK NAME:** Olivine microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 11 | 19 | 0.2–3.0 | | Euhedral–subhedral | Euhedral grains occur as inclusions in cpx and plag. Partially replaced by talc, tremolite, and opaques. |
| Plagioclase | 53 | 53 | 0.4–4.0 | | Anhedral | Some subhedral crystals. Most large grains are anhedral. Small grains in cpx are euhedral. |
| Clinopyroxene | 25 | 28 | 1–10 | | Subhedral–euhedral | Anhedral grains are oikocrysts with, most commonly, plag chadacrysts. Rare ol pseudomorphs (now brown and/or pale green amphibole) chadacrysts. |
| Orthopyroxene(?) | Tr | Tr | | | | |
| Opaques | Tr | Tr | 50.5 | Fe-Ti | Subhedral | Inclusions in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Replacing ol along cracks. Dirty yellow clay with high birefringence. Partial replacement of cpx. |
| Carbonate | Tr | Ol | |
| Actinolite | 2 | Ol, cpx, veins | Pale green replacing ol. Along cracks in plag and rimming cpx. Acicular, anhedral crystals, ≈0.5 mm in size. Colorless tremolite crystals, up to 1 mm in size. |
| Hornblende | 3 | Cpx, ol | Occurs along the margins of cpx and ol crystals. Also occurs as intergrowths with cpx (symplectitic structure). |
| Talc | 4 | Ol | <0.5 mm crystals occurring between ol and plag crystals, or plag and tremolite (replacing ol) crystals. |
| Opaques | Tr | Ol | Occurs with tremolite which replaces ol. In cpx along cleavage planes. |

**COMMENTS:** Deformation is negligible. Ol show slightly wavy extinction. Plag is partially recrystallized.
One ol crystals is markedly elongate, W:L = 0.4:4.0 mm. The long axis of this crystal lies parallel to the foliation. One cpx oikocryst is 8 mm long.
Systematic (????) grain size variation is present in the thin section.
Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-17R-1 (Piece 5, 22–27 cm)**

**ROCK NAME:** Olivine gabbro / porphyroclastic olivine gabbro

**WHERE SAMPLED:** Sharp contact between undeformed and porphyroclastic olivine gabbro

**TEXTURE:** Orthocumulus to mesocumulus / porphyroclastic

**GRAIN SIZE:** Fine to coarse (0.3–10 mm) / fine to medium (0.01–4.00 mm) **OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 4 | 0.5–1.0 | | Rounded, irregular | Interstitial. Altered to talc, tremolite, chlorite. Kinked crystals. Granoblasts. |
| Plagioclase | 30 | 60 | 510 | | Euhedral, rounded | Large crystals included in cpx. Other crystals severely deformed. |
| Clinopyroxene | 6 | 32 | 1–10 | | Anhedral–subhedral, irregular | Very large phenocrysts. Interstitial phase. |
| Orthopyroxene | 2 | 5 | 54 | | | Interstitial phase. Extremely altered to complex intergrowths of tremolite + magnetite. Green amphibole more abundant in the deformed part of the slide. |
| Ilmenite | Tr | Tr | <0.5 | | Anhedral | Associated with opx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Olive green, replacing ol along cracks. |
| Chlorite | Tr | Ol, plag | Gray birefringence. Occurs between plag and altered ol crystals. |
| Tremolite/ actinolite | 4 | Ol, opx | Interlocking fibers, 0.02–0.20 mm thick. Forms pseudomorphs after magnesian phases. |
| Hornblende | 20 | Cpx | Green to green-brown pseudomorphs after cpx. |
| Plagioclase | 30 | Plag | Neoblasts. Some neoblasts in strained plag. Most common in porphyroclastic gabbro. |
| Brown amphibole | 3 | Cpx | Occurs in patches around large cpx crystals. Sometimes associated with plag veins. |
| Blue-green amphibole | 2 | Amphibole, plag | Blue-green to pale yellow-brown pleochroism. Rims cpx and in veins in plag crystals. |
| Magnetite | 1 | Ol, opx | Reaction products associated with tremolite. Crystals 0.02–0.20 mm in size. |

**COMMENTS:** The undeformed and porphyroclastic sections of the thin section correspond to ol gabbro. It is possible that the porphyroclastic gabbro contained more original opx than the undeformed ol gabbro, based on the metamorphic assemblages.

Well defined zonations in opx replacement:
  core: coarse tremolite, magnetite, or fresh opx
  margin: fibrous tremolite, blue-green amphibole
Well defined olivine replacement:
  core: fresh ol or ol + tremolite + magnetite
  intermediate: coarse tremolite + magnetite
  margin: fibrous tremolite ± talc ± chlorite or brown or blue-green amphibole.
Myrmekitic intergrowth of brown amphibole + cpx.

## THIN SECTION DESCRIPTION

**118-735B-18R-2 (Piece 17, 143–146 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Medium to coarse **OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1.2 | 14 | 2–7 | | Amoeboid, anhedral | No evidence of strain (probably due to extensive alteration). |
| Plagioclase | 52.2 | 56 | 2–6 | An 62 | Subhedral–euhedral | Twin lamellae in plag are rarely bent, but some crystals pinch out. Occasional cross-hatch twins suggestive of minor strain. |
| Clinopyroxene | 25.2 | 30 | 2–10 | | Subhedral–euhedral | Exsolution lamellae and parting planes in cpx are straight. Cpx oikocrysts enclose plag crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 0.2 | Ol | Carbonate (aragonite?) + opaque clay (hematite?) replace ol cores. |
| Chlorite | 4.6 | Plag, ol | |
| Tremolite | 6.2 | Ol | Talc + tremolite completely replace ol and form coronas around ol relicts and pseudomorphs (carbonate + opaques). Talc + tremolite coronas are often surrounded by a zone of chlorite which borders plag. |
| Hornblende | 4.8 | Cpx, veins | |
| Talc | 1.6 | Ol | |
| Amphibole | 1.4 | Plag | |
| Opaques | 2.6 | Ol | |

**COMMENTS:** Percentages based on 2000 point counts.
Sample is remarkably undeformed. No recrystallization and only minor evidence of strain.
Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-18R-3 (Piece 3, 29-31 cm)**

**ROCK NAME:** Meta-microgabbro

**WHERE SAMPLED:** Fine-grained thick layer in coarse-grained gabbro

**TEXTURE:** Tabular, granular

**GRAIN SIZE:** 1.0–0.5 mm, fine

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | | ? | 0.5 | | Subhedral | Replaced by actinolite, talc and chlorite. No ol left. |
| Plagioclase | 40 | 45 | 0.2-0.6 | | Anhedral | Showing wavy extinction, locally recrystallized, replaced by albite, epidote and chlorite. |
| Clinopyroxene | 1 | ? | 0.5-1.0 | | | Replaced by actinolite, bluish-green and brown hbd. At the core, a few amphibole and cpx aggregates are preserved. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 5 | Ol? | Replacing part of olivine (and cpx?) present between plag and actinolite aggregate, radial aggregate. |
| Epidote | 2 | Plag | Replacing plag, euhedral or dusty aggregate. |
| Actinolite | 20 | Opx, ol? | At the core of aggregates replacing ol(?)-cpx 0.1–0.2 mm aggregate. |
| Hornblende | 2 | Opx, ol | Brown, anhedral. In actinolite aggregate replacing opx ? Replaced by bluish-green amphibole. |
| Plagioclase | 3 | Plag | Albite, replacing plag by vein network. |
| Hornblende | 24 | Cpx vein | Bluish-green, euhedral, replacing cpx, locally filling vein. |
| Mica | 2 | Ol ? | Between actinolite aggregate and plag, probably replacing ol. 0.1mm present as aggregate. Talc? |

**COMMENTS:** Because of severe replacement of cpx and ol, it is difficult to determine original mineral abundance. It could be a fine-grained, ol-rich gabbro (troctolite) or opx-rich gabbro. Rough grain boundary geometry is preserved, indicating weak deformation. Plag and mafic pseudomorph show foliation.

## THIN SECTION DESCRIPTION

**118-735B-18R -3 (Piece 4, 37-40 cm)**

**ROCK NAME:** (Olivine?) microgabbro

**WHERE SAMPLED:** Fine-grained zone between coarse-grained gabbro

**TEXTURE:** Tabular, granular

**GRAIN SIZE:** 1.0-1.5 mm

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | ? | 1.0-4.0 | | | No relict preserved, aggregate of tremolite at the core and chlorite at the margin. |
| Plagioclase | 45 | 50 | 0.3-1.2 | | Anhedral | Veined by albite, amphibole and chlorite locally granulated, wavy extinction common. |
| Clinopyroxene | 7 | 15 | 1.0-2.0 | | Subhedral-anhedral | Replaced by various amphiboles, some are pale green. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 1 | Vein | In crack cutting other structures, 0.1mm thick, also occurs replacing plag as irregular veinlets. |
| Chlorite | 7 | Ol, plag, vein | Replacing ol margin, 0.1–0.2 mm in size, occurs as aggregate locally, relict and replacing plag. |
| Actinolite | 25 | Cpx, vein | Replacing cpx, in veins up to 0.5 mm thick, euhedral laths and irregular anhedral shapes forming aggregate. |
| Hornblende | 3 | Cpx, ol | Brown, along the margin of cpx and ol pseudomorph. Ol pseudomorph replaced by actinolitic amphibole. |
| Albite | 2 | Plag (vein) | 0.1-0.4 mm thick veinlets in plag. |
| Tremolite | 5 | Ol ? | Replacing ol core, up to 8.0 mm long, radial aggregate common. |
| Hornblende | 5 | Cpx ? | Euhedral lath replacing cpx(?), up to 0.4 mm long. |

**COMMENTS:** It is difficult to determine the original modal abundance because of almost complete replacement of mafic minerals. The amount of amphibole pseudomorphs of cpx shows that the cpx mode was originally at least 15%. One large pseudomorph composed of tremolite and chlorite can easily be identified as ol. Weak foliation is present.

Point count based on 1500 points:

| | | |
|---|---|---|
| Plag: | Primary | 11.4 |
| | Metamorphic | 18.5 |
| | Replacement | 3.9 |
| Cpx: | | 0.4 |
| Amphibole: | Brown | 2.0 |
| | After cpx | 27.2 |
| | Actinolite | 14.9 |
| | After first generation of amphibole | 14.9 |

## THIN SECTION DESCRIPTION

**118-735B-19R-2 (Piece 12, 98-100 cm)**

**ROCK NAME:** Amphibolitized metagabbro

**WHERE SAMPLED:** Shallow ridge—east wall

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 5 | | | | Pseudomorphed by talc-tremolite. |
| Plagioclase | 18 | 50 | | | | Replaced by amphiboles/clays on boundaries. |
| Clinopyroxene | 5 | 45 | | | | Nearly completely replaced by amphibole, only small fragments left in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 4 | Plag | Replacing of plag and on grain boundaries with a fine amphibole. |
| Chlorite | 12 | Cpx | In some fibrous amphibole clots. |
| Actinolite | 10 | | Fibrous amphibole filling fractures in analcime |
| Hornblende | 2 | Cpx | Brown, blebs and rims on some cpx replacements. |
| Plagioclase | 17 | Plag | 0.2 mm, broken and partially recrystallized. |
| Opaques | 1 | Ol/cpx | Fine, disseminated around mafic pseudomorphs. |
| Talc | 2 | Ol | |
| Tremolite | 3 | Ol | Clear amphibole. |
| Amphibole | 32 | Cpx | Light green to green amphibole in blotchy to fibrous patches after cpx. |
| Analcime | 5 | Veins | Occurs with actinolite fibers. |

**COMMENTS:** Sample has no foliation but has undergone brittle deformation. Plag is extensively granulated and recrystallized, but there is no evidence of extensive albitization. There are numerous fractures which clearly have some offset between them; these fractures are filled with fibrous amphibole and analcime. The larger veins are roughly subparallel, although they do cross.

## THIN SECTION DESCRIPTION

**118-735B-19R-3 (Piece 6A, 73-75 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Granular
**GRAIN SIZE:** Fine to coarse
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2.8 | 6 | 0.2-4.0 | | Anhedral | Fractured aggregates with tremolite and talc alteration. |
| Plagioclase | 40.3 | 55 | 0.1-6.0 | | Anhedral | Bent porphyroclasts with undulose extinction. |
| Clinopyroxene | 8.0 | 30 | 1-6 | | Anhedral | Extensively amphibolitized. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3.0 | Cpx, plag | Brownish aggregates after cpx, in plag. |
| Chlorite | 0.2 | Cpx | In actinolite clots. |
| Actinolite | 27.2 | Cpx, Ol | Mixture of tremolite, actinolite, actinolitic hbd. Aggregates of needless. Pale to light green pleochroism. |
| Hornblende | 0.5 | Cpx | Brown. Small patches in cpx. |
| Plagioclase | 14.6 | Plag | Crystals <0.1 mm. Many crystals have sutured boundaries. |
| Opaques | 1.0 | Ol | Fine-grained opaques in ol pseudomorphs. |
| Tremolite | 2.0 | Ol | After ol. |
| Talc | 0.4 | Ol | After ol. |

**COMMENTS:** Percentages based on 1450 point counts.
No well-developed foliation but extensive plag granulation and recrystallization.

## THIN SECTION DESCRIPTION

**118-735B-19R-3 (Piece 12A, 128-132 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic-granular, cataclastic
**GRAIN SIZE:** Coarse (fine where granulated)
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 10 | 15 | 5-10 | | Anhedral |
| Plagioclase | 40 | 60 | 5-15 | | Anhedral |
| Clinopyroxene | 13 | 25 | 5-15 | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Replacing ol along fractures |
| Chlorite | Tr | Ol | |
| Tremolite/ actinolite | 5 | Ol | |
| Actinolite | 9 | Veins, cpx | Partially replacing cpx. |
| Plagioclase | 20 | Plag | Neoblasts. |
| Brown amphibole | 3 | Cpx | Patchy replacement of cpx and interstitial between cpx neoblasts. Also lining grain boundaries between cpx and plag crystals. |
| Talc | <1 | Ol | |
| Magnetite | <1 | Ol | |

**COMMENTS:** Plag shows some plastic deformation and granulation along grain boundaries. Cpx shows some plastic deformation, but less than plag. Recrystallized areas associated with brown amphibole are granulated (forming neoblasts) in some areas.

## THIN SECTION DESCRIPTION

**118-735B-19R-5 (Piece 6, 47-50 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10.0 | 65 | 1-3 | | Anhedral | Porphyroclasts with undulose extinction. |
| Clinopyroxene | 9.1 | 30 | 1-3 | | Anhedral | Bent, partially replaced crystals. |
| Orthopyroxene | 4.4 | 5 | 2-6 | | Subhedral | Some granulation. Partial replacement at crystal margins. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3.0 | Plag | Fine, dusty alteration in cores and boundaries of some plag crystals. |
| Actinolite | 15.2 | Cpx, opx, veins | Green to colorless, fibrous amphibole replacing px and filling veins. |
| Hornblende | 1.1 | Cpx | Brown. A few patches in cpx and in opaque intergrowths. |
| Plagioclase | 52.0 | Plag | <0.1 mm neoblasts with sutured boundaries. |
| Opaques | 0.8 | Cpx | 0.02–0.10 mm crystals in cpx. |
| Opaques | 1.0 | Cpx(?) | 1–2 mm, anhedral crystals on one side of the slide (Fe-stained). Probably ilmenite. Possibly primary. |
| Clinopyroxene | 3.4 | Cpx | Neoblasts, 0.1 mm in size. Colorless to pale green. |

**COMMENTS:** Percentages based on 1600 point counts.
Opx definitely occurs in slide: high 2Vx. Most abundant in one corner of the slide.
Intergrowth of ilmenite(?) (gray-white in reflected light, anhedral, 0.1–3.0 mm in size) with green-brown amphibole (0.05–0.10 mm in size) is possibly primary.

## THIN SECTION DESCRIPTION

**118-735B-19R-5 (Piece 16, 126-129 cm)**

**ROCK NAME:** Metagabbro (metatroctrolite?)

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium grained

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | ? | 0.1 | | Anhedral | Fragments left on one corner |
| Plagioclase | 40 | 45 | 0.1-2.0 | | Subhedral | Granular aggregates with recrystallized boundaries. |
| Clinopyroxene | 3 | ? | 4.0 | | Poikilitic | Large poikilitic grain on one side. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | A little around talc-tremolite aggregates. |
| Carbonate | 1 | Ol | Rarely in core of ol pseudomorphs. |
| Actinolite | 26 | Ol, cpx | Probably tremolite/actinolite mix. Clear to light green aggregates of amphibole needles after mafics, with coronas of talc. |
| Hornblende | 1 | | Rarely in some talc–tremolite clots. |
| Opaques | 1 | Ol | Usually in clots with carbonate, probably after ol. |
| Talc | 26 | Ol, cpx | As light brown aggregates between amphibole clots and plag, often overlapping edges of plag. |

**COMMENTS:** From minicore in a fine-grained section with a sharp contact to coarse-grained section. Original ol-cpx proportions difficult to determine. Core is taken at what should be across the foliation, but shows mostly a static recrystallization. Some banding of plag and deformation twins. Plag originally a neoblast, but distinction difficult to make—appears to have been very ol-rich, possibly troctolite.

118-735B-20R-1 (Piece 2B, 29-33 cm)

## THIN SECTION DESCRIPTION

**ROCK NAME:** Contact, coarse olivine-gabbro

**WHERE SAMPLED:** Fine-grained troctolitic gabbro

**TEXTURE:** Ortho- to mesocumulus

**GRAIN SIZE:** Coarse- to fine-grained

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO- SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 2 | 0.04-3.0 | | Rounded ? | Strained and kinked, preferred orientation. |
| Plagioclase | 45 | 65 | 1.0-3.0 | | Irregular, replaced | Strained and recrystallized into smaller granoblasts replaced by talc and prehnite. |
| Clinopyroxene | 25 | 33 | 2.0-7.0 | | Anhedral–subhedral | Always filling space between ol and plag. In coarse-grained part they are oikocrystic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Dark green-brown in cracks. |
| Chlorite | Tr | Ol | Grey birefringence associated with actinolite. |
| Actinolite/tremolite | 1 | Ol | Mixed with talc around ol grains, fibers of prismatic crystals 0.5 mm. |
| Hornblende | 6 | Cpx | Green-brown pseudomorphs after cpx. |
| Plagioclase | 14 | Plag | Granoblasts more abundant in the coarse gabbro. |
| Amphibole | 1 | Tr. | Brown, included in replaced cpx, more abundant in coarse-grained gabbro. |
| Talc | 1 | | Fibrous, radiating from ol to plag mixed with light-green amphibole. |
| Magnetite | Tr | Ol | Very minute grains, 0.05 mm spread around ol. |
| Clinopyroxene | 5 | Cpx | Granoblasts around larger primary cpx. |
| Prehnite | 1 | Plag | Light green, fibrous, form embayment in plag. |

**COMMENTS:** Estimation of ol difficult because talc invades plag and may lead to an overestimation of ol and underestimation of plag. There is, however, a modal change in proportion of phases; the fine-grained gabbro being troctolitic and the coarse-grained, ol-rich. Talc is the major replacement phase with tremolite/actinolite. Presence of brown amphibole is related to change in composition of the rock, but is subordinate.

118-735B-20R-2 (Piece 1C, 10-13 cm)

## THIN SECTION DESCRIPTION

**ROCK NAME:** Amphibolite

**WHERE SAMPLED:**

**TEXTURE:** Weakly foliated

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO- SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 40 | 1.0-3.0 | | Anhedral | Porphyroclasts. |
| Clinopyroxene | - | 60 | 1.0-4.0 | | | Porphyroclasts replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 14 | Plag | Also in vein, replaces large crystals and neoblasts. |
| Epidote | 1 | Plag | Also in vein; zoisite, blue interference colors. |
| Tremolite | Tr | | Clot in corner of slide. |
| Hornblende | 55 | Cpx, vein | Brown. |
| Plagioclase | 5 | Plag | Neoblasts around plag. |
| Hornblende | 5 | Veins | Green to blue pleochroism, coarse, euhedral, rims on brown hbd. |

**COMMENTS:** Rock was deformed and cpx replaced by green-brown amphibole. Probably at the same time since green-brown hbd has mosaic texture with no cpx neoblasts. Late fracturing created vein in which hbd neoblasts recrystalized to large euhedral crystals. Plagioclase porphyroblasts and neoblasts are asts albitized.

## THIN SECTION DESCRIPTION

**118-735B-20R-2 (Piece 2, 23-27 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic, foliated

**GRAIN SIZE:** Very coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 30 | | 2.0-10.0 | | | Porphyroclast replaced by tremolite. |
| Plagioclase | - | ? | | | | Recrystallized relicts only. |
| Clinopyroxene | 10 | ? | | | | Mostly replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 15 | | Replacing green neoblasts and porphyroclasts of cpx and plag. |
| Hornblende | 2 | Cpx | Brown, replacing pyroxene and recrystallized neoblasts. |
| Plagioclase | 15 | | Neoblasts. |
| Magnetite | 6 | | Colorless. |
| Talc | 2 | | |
| Tremolite | 20 | Ol or ol and plag | |

**COMMENTS:** Neoblasts of plag, pyroxene and ol are extensively replaced by tremolite-talc–magnetite (ol) or actinolite (plag–ol or plag–cpx). Opaques are concentrated in intersticies.

## THIN SECTION DESCRIPTION

**118-735B-20R-2 (Piece 2, 23-27 cm)**

**ROCK NAME:** Troctolite or plagioclase-bearing dunite

**WHERE SAMPLED:** Olivine-rich portion in gabbro

**TEXTURE:** Porphyroclastic, foliated

**GRAIN SIZE:** Coarse to medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 50 | 78 | 0.5-6.0 | | Subhedral—anhedral | Containing significant opaques (magnetite and chromium spinel) and anthophyllite. |
| Plagioclase | - | 15 | 0.2-1.0 | | Anhedral, polygonal | Polygonized, always as aggregate. |
| Clinopyroxene | 3 | 5 | 0.5-2.0 | | Anhedral | Replaced by brown to pale green amphibole. |
| Spinel | 1 | 2 | 0.2-1.0 | $Fe^{3+}$ - rich | Euhedral—subhedral | Some are replaced magnetite. |
| Brown hornblende | | | 0.1-0.5 | | Anhedral | Rimming cpx and ol and replacing cpx. Possibly secondary. |
| Phlogopite | Tr | Tr | 0.1 | | Anhedral | Between ol and cpx inclusion in ol. Brown, strong pleochroism. Possibly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Replacing ol along its margins and cracks. |
| Actinolite | 11 | Cpx, brown hbd | Rimming tremolite, replacing cpx and brown hbd. |
| Hornblende | 4 | Cpx, ol | Brown, rimming cpx and ol, commonly accompanying spinel, also replacing cpx. |
| Plagioclase | 10 | Plag | Polygonal aggregate after primary large plag. |
| Anthophyllite | 2 | Ol | As inclusions in ol, euhedral, long laths, 0.1-0.7 mm long. |
| Tremolite | 7 | Ol | replacing ol from the margins. |
| Talc | 8 | Ol, plag | Between plag and tremolite, actinolite aggregate after ol. |
| Fe-Ti oxide | 2 | Ol, spinel | Accompanying tremolite after ol, 0.2 mm sized inclusions in ol, it also replaces chromium (?) spinel, altered cpx. |
| Hematite | Tr | | Exsolution in cpx and ol. Also has opaque lamellae. |

**COMMENTS:** Difficult to estimate abundance of plag because it is also replaced by amphibole, as well as cpx and ol. At the boundary of coarse-grained (approximately 5 mm) and fine-grained (approximately 2mm) layers, plag is more then 20%. Ol contains many magnetite grains, fluid inclusions and euhedral anthophyllite, suggesting it is metamorphic. Ol sub-grain boundaries indicate deformation.

## THIN SECTION DESCRIPTION

**118-735B-21R-2 (Piece 1B, 53-56 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.0 | 5.7 | 2.0-5.0 |  | Anhedral | Kink bands in ol. |
| Plagioclase | 51.9 | 60.5 | 2.0-8.0 |  | Anhedral | Highly strained, partly recrystallized. |
| Clinopyroxene | 29.6 | 33.8 | 3.0-5.0 |  | Anhedral |  |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 0.4 | Ol, plag | In reaction coronas around tremolite pockets (ol pseudomorphs). |
| Tremolite | 1.5 | Ol | Reaction coronas around ol, together with talc. |
| Hornblende | 3.9 | Cpx, veins |  |
| Plagioclase | 8.6 |  | Neoblasts (wide range in size). |
| Clinopyroxene | 0.3 |  | Neoblasts intergrown with hbd in interstitial areas. |
| Opaques | 0.1 |  |  |
| Talc | 0.7 | Ol | In reaction coronas with tremolite replacing ol. |

**COMMENTS:** Plag has been recrystallized but not transported. Few igneous twins remain. Cumulate texture largely retained. Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-21R-2 (Piece 1B, 49-51 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulus

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 7 |  |  |  | Minor kink banding, ol partially surrounds cpx. |
| Plagioclase | 40 | 50 |  |  |  | Porphyroclasts of plag. |
| Clinopyroxene | 35 | 43 |  |  |  | Porphyroclasts of plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite | 2 | Ol | In coronas around ol relicts. |
| Hornblende | 1 | Cpx | Brown. |
| Plagioclase | 10 | Plag | Neoblasts. |
| Talc | 2 | Ol | Intergrown with tremolite in reaction coronas, around ol. |
| Ampnibole | 2 | Cpx | Blue-green, replacing cpx and filling veins. |
| Clinopyroxene | 3 | Cpx | Neoblasts. |

**COMMENTS:** Plag is highly strained and partially recrystallized, but not noticeably stretched. One set of amphibole veins are parallel to the length of this oriented slide, i.e. they are vertical. Second set of veins dip at a 45° angle. This set is characterized by amphibole in addition to narrow zones of recrystallization. The two sets may be contemporaneous.

## THIN SECTION DESCRIPTION

**118-735B-20R-2 (Piece 3D, 54-56 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:**
**GRAIN SIZE:**
**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6 | 7 | 2.0-6.0 | | Anhedral | Rimmed by tremolite (or actinolite), opaques and talc, less than 0.3 mm thick. Locally brown hbd and cpx are present at the rim. |
| Plagioclase | 61 | 61 | 0.5-10.0 | | Subhedral–anhedral | Veined by pale green amphibole. Grain size shows wide variation. |
| Clinopyroxene | 31 | 32 | 5.0-12.0 | | Anhedral | Replaced by brown hbd and actinolitic pale-green amphibole. |
| Opaque | Tr | Tr | 0.1-0.2 | | Subhedral–anhedral | In the margins of ol and cpx commonly accompanied by brown amphibole. |
| Orthopyroxene | Tr | Tr | 0.1 | | Subhedral– | As blebs in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | | Ol | Brown, filling cracks in ol. |
| Chlorite | 0.1 | Cpx, plag | In crack? In cpx, radial aggregate. |
| Actinolite | 0.1 | Cpx, veins | Replacing cpx/brown hbd, veining plag. |
| Hornblende | 0.7 | Cpx, ol | Rimming cpx and ol and replacing cpx. |
| Talc | 0.7 | Ol | Rimming ol, up to 0.3 mm long. |
| Tremolite | 0.2 | Ol | Rimming ol, grading into actinolite outward from ol. |
| Fe-Ti oxide | 0.1 | Ol, cpx | Accompanied by tremolite. Actinolite which replaces ol is also present along cracks and in cpx. |

**COMMENTS:** Cpx grains extend to the ol and plag grain boundary as a thin film or plate (0.1-2.0 mm thick). Ol has many kink bands showing a deformation event.

## THIN SECTION DESCRIPTION

**118-735B-21R-2 (Piece 1C, 57-63 cm)**

**ROCK NAME:** Gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular
**GRAIN SIZE:** Very coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1.6 | 5 | 5.0-8.0 | | Anhedral | Strain lamellae. |
| Plagioclase | 64.8 | 65 | 10.0-25.0 | | Anhedral | |
| Clinopyroxene | 25.7 | 30 | 8.0-38.0 | | Anhedral | Thin exsolution lamellae, probably opx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Magnetite | 0.1 | Ol | |
| Amphibole | 4.6 | Cpx | Green. Actinolite, green to blue-green, filling thin fractures. |
| Amphibole | 1.8 | Ol | Colorless. Tremolite. |
| Talc | 0.9 | Ol | |
| Amphibole | 0.5 | Cpx | Interstitial. |

**COMMENTS:** Alteration of ol includes colorless amphibole in the core, rimmed by a ring of oxides and an overgrowth of fibrous green amphibole and talc. Radial growth being away from the ol. Cpx encloses euhedral feldspars. Also shows some static recrystallization to a homogeneous cpx and rod-like inclusions of opx.

## THIN SECTION DESCRIPTION

**118-735B-22R-1 (Piece 9, 78-80 cm)**

**ROCK NAME:** Foliated metagabbro with vein

**WHERE SAMPLED:**

**TEXTURE:** Foliated, veined

**GRAIN SIZE:**

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Clinopyroxene | 0 | 50 | 2.0-10.0 |  | Anhedral | Replaced by brown hbd (pale), slightly recrystallized. |
| Plagioclase | 43 | 50 | 1.0-3.0 |  |  | Recrystallized along edges, broken. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr |  | In albite vein. |
| Albite | 5 | Plag | Edges of plag near vein. |
| Actinolite | Tr |  | In vein, euhedral crystals. |
| Hornblende | 50 | Cpx | Blue-green, in vein and matrix. |
| Plagioclase | 2 | Plag | Neoblasts. |

**COMMENTS:** Cut by vein. Edges of vein appear to be broken fragments, suggesting a shear zone. Plag is cut by anastomosing network of albite. Rock possibly altered to amphibolite mineralogy prior to deformation. Final event was shearing along which highly pleochroic blue-green amphibole is forming.

## THIN SECTION DESCRIPTION

**118-735B-22R-2 (Piece 1C, 44-46 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulus

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 55 | 65 | 0.1-4.0 |  | Euhedral | As very small grains or broken into sub-grains in the matrix. Recrystallized. |
| Clinopyroxene | 5 | 25 | 0.3-3.0 |  | Irregular, | Nearly completely replaced by amphibole. Interstitial |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | Plag | Straining in dark brown plag (nearly opaque). |
| Tremolite | 5 | Cpx | Fibrous, replacing irregular grains of unknown composition. Found at edges on inside of plag. |
| Hornblende | 28 | Cpx | Green-brown pseudomorphs. |
| Amphibole | 2 | Amphibole | Blue-green. Lining the outer margins of amphibole pseudomorphs, or totally replacing it (or tremolite). |
| Amphibole | Tr | Cpx | Mostly at outer margins of amphibole grains. Some included in amphibole along cleavages. |

**COMMENTS:** Pseudomorphs replaced by tremolite and blue-green amphibole are of unknown original composition: could be ol or opx. Rock severely altered at medium and low temperatures (formation of clays, difficult to estimate volumetrically), obscuring some of the primary features.

## THIN SECTION DESCRIPTION

**118-735B-22R-2 (Piece 1C, 61-63 cm)**

**ROCK NAME:** Amphibolitized olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic (crushed)

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 5-10 | 4.0 | | | Replaced by tremolite, actinolite and clays |
| Plagioclase | Tr? | 65 | 5.0 | | | Albitized and fractured. Difficult to evaluate percentage |
| Clinopyroxene | — | 30 | 4.0 | | | Replaced by green hornblende. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Cores of some tremolite-actinolite alteration zones. |
| Albite | 65? | Plag | Difficult to evaluate percentage; plag is very white in sample. |
| Actinolite and tremolite | 5-10 | Ol | |
| Hornblende | 5 | Cpx, veins | |

**COMMENTS:** Unfoliated rock. Secondary minerals developed during static alteration of primary minerals and in fractures. Deformation was cataclastic. No recrystallization of plag.

## THIN SECTION DESCRIPTION

**118-735B-22R-2 (Piece 3B, 86-91 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 17.8 | 20 | 5.0-10.0 | | | Strain lamellae, highly fractured but fresh. |
| Plagioclase | 32.6 | 35 | 5.0-10.0 | | | |
| Clinopyroxene | 38 | 45 | 5.0-12.0 | | | Exsolution lamellae of opx. |
| Orthopyroxene | Tr | | | | | Rimming some ol and exsolved from cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.3 | Ol | |
| Chlorite | Tr | Ol | |
| Talc | 1.2 | Ol | |
| Amphibole | 1.2 | | Brown. Replacing cpx and in alteration patch adjacent to ol. |
| Magnetite | 1.5 | Ol | |
| Amphibole | 0.5 | Ol | Colorless. |
| Amphibole | 3.5 | Cpx | Green. Replacing cpx and in thin fractures. |
| Clinopyroxene | 2.7 | | Recrystallized from primary cpx. |

**COMMENTS:** Cpx shows some static recrystallization to homogeneous cpx with rod-like inclusions of opaques and blebs or rods of opx. Brown amphibole present.

## THIN SECTION DESCRIPTION

**118-735B-22R-3 (Piece 5A, 110-115 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.3 | 7 | 0.2-5.0 | | Anhedral | Almost completely altered. Fresher in coarse-grained areas. |
| Plagioclase | 53.0 | 55 | 0.3-0.8 | | Anhedral | |
| Clinopyroxene | 10.9 | 38 | 1-8 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.7 | Ol | |
| Chlorite | 1.7 | Veins, ol | In veins and in alteration products of ol. |
| Amphibole | 29.3 | Cpx, plag | Green. Replacing cpx and filling fractures in plag. |
| Amphibole | Tr | Cpx | Brown. |
| Amphibole | 2.4 | Ol | Colorless. |
| Talc | 0.1 | Ol | |
| Sphene | 0.1 | Magnetite, cpx | Replacing Ti-magnetite in highly altered areas of cpx. |
| Magnetite | 0.5 | Ol | |

**COMMENTS:** Grain size varies over the length of the slide. The top 2 cm of the slide are coarse-grained (4-8 mm); the lower 2 cm are medium-grained. Minor static recrystallization of cpx. Note: one vein has euhedral amphibole growing into a void. This void was ultimately filled by clay minerals.

## THIN SECTION DESCRIPTION

**118-735B-22R-3 (Piece 5A, 118-120 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral, granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.9 | 7 | 0.5-0.8 | | Anhedral | Rounded to elongate, often in cpx or on cpx edges. |
| Plagioclase | 40 | 40 | 1.0-3.0 | | Anhedral | |
| Clinopyroxene | 18.7 | 53 | 1.5-4.0 | | Anhedral | Enclose small ol and plag. |
| Opaques | Tr | Tr | 0.1 | | Subhedral | Present at the rim of cpx and ol crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Ol | In center of pseudomorphs mixed with talc. |
| Chlorite | 2 | Cpx | In actinolitic clots. |
| Actinolite | 33.9 | Cpx, ol | Light green fibrous to patchy replacement. Also in vein; includes some brown amphibole crystals. |
| Hornblende | Tr | Cpx | Brown. |
| Talc-tremolite | 0.5 | Ol | Lenses around ol. |
| Magnetite | 1 | Ol | Fine grains in ol and cpx replacements. |

## THIN SECTION DESCRIPTION

**118-735B-23R-1 (Piece 6, 46-52 cm)**

**ROCK NAME:** Partly amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Fine to medium and coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 72 | 72 | 0.2-0.4 | | Anhedral-subhedral | Slightly strained, little recrystallization into polygonal grain. |
| Clinopyroxene | 16 | 23 | 0.5-5.0 | | Anhedral-subhedral | Partially replaced cpx by green and brown amphibole. |
| Opaques | 4 | 5 | 0-4.0 | | Anhedral | Related to brown amphiboles, surround silicates (pore space). |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 5 | Cpx | Thin fibers growing throughout the grains. |
| Brown hornblende | 2 | Cpx | Rims around cpx, or in small cracks or fractures (cut everything). |
| Magnetite | 1 | Cpx | Associated with brown amphibole, 0.01-0.3 mm. |

**COMMENTS:** Very fresh, small amount of opaques appear to be primary. Coarse-grained (>3 mm) part of the sample contains 83% plag, 15% cpx (7% altered to amphibole), 2% opaques (1% altered to magnetite).

## THIN SECTION DESCRIPTION

**118-735B-23R-2 (Piece 1B, 34-36 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulus to orthocumulus

**GRAIN SIZE:** Medium

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.7 | 5.5 | 2.0-5.0 | | Subhedral | Kink banding in ol. |
| Plagioclase | 53.2 | 54.4 | 1.0-6.0 | | Anhedral–subhedral | Large grains recrystallized to smaller polygonal grains, but not stretched or displaced. |
| Clinopyroxene | 33.8 | 40.1 | 2.0-7.0 | | Subhedral | Minor recrystallization of cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Ol | |
| Chlorite | 1.2 | Ol, plag | Possibly clay veining ol. |
| Actinolite/tremolite | 1.4 | Ol, plag | In reaction coronas around ol. |
| Hornblende | 6.3 | Replacing cpx and filling veins | Veins dip at 40° in oriented thin section. |
| Talc | 0.2 | Ol | Intergrown with tremolite. |
| Opaques | 0.2 | Ol, cpx | Intergrown with hornblende in reaction zone between ol and cpx. |

**COMMENTS:** Original cumulus texture mostly preserved. Igneous lamination dipping at about 45° defined by subparallel alignment of cpx and ol and original plag grains. Alignment of plag now obscured by recrystallization to smaller grains. Subparallel amphibole grains oriented normal to igneous lamination.

## THIN SECTION DESCRIPTION

**118-735B-23R-2 (Piece 1C, 42-48 cm)**

**ROCK NAME:** Microgabbro
**WHERE SAMPLED:**
**TEXTURE:** Foliated
**GRAIN SIZE:** Coarse
**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 2 | 0.3 | | | Adjacent gabbro has ol. Proportions from adjacent microgabbro. |
| Plagioclase | 20 | 45 | 0.3 | | | |
| Clinopyroxene | 5 | 52 | 0.3 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Epidote | 1 | Plag, zoisite | |
| Actinolite | Tr | | Within amphibole vein, late low temperature replacement. |
| Sphene | 1 | Ilmenite | |
| Hornblende | 46 | Cpx | Olive-green-brown, green on edges. Neoblasts on margin syn-deformational. |
| Plagioclase | 22 | Plag | Neoblasts recrystallize albitized zones. |
| Ilmenite | 4 | | |

**COMMENTS:** Foliated zone in an ol-bearing microgabbro. This microgabbro is present in only one corner of the slide. Ilmenite is parallel to the foliation and concentrated within the coarsest part of the slide. Veins of coarse amphibole oblique to the foliation crosscut the ilmenite and are not deformed. Plag is more recrystallized than deformed.

## THIN SECTION DESCRIPTION

**118-735B-23R-2 (Piece 1A, -73 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Orthocumulate
**GRAIN SIZE:** Coarse
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 15 | 8.0 | | | Altered into tremolite and talc, faint deformation sub-grain boundaries. |
| Plagioclase | 70 | 70 | 8.0 | | | Fresh, some deformation kinks. |
| Clinopyroxene | 7 | 15 | 8.0 | | | Altered into brown and green amphibole, not deformed. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite | 2 | Ol | |
| Hornblende | 9 | Cpx, veins | Green and brown. |
| Talc | 2 | Ol | |

**COMMENTS:** Relatively fresh gabbro, almost undeformed (just some kinks, no recrystallization).

## THIN SECTION DESCRIPTION

**118-735B-23R-3 (Piece 2, 34-37 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular/symplectite

**GRAIN SIZE:** Coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | | ? | | | | Due to deformation and metamorphism it is not clear whether ol is present or not. |
| Plagioclase | 20.0 | 20.7 | 1.0-2.0 | | Subhedral | Wavy extinction, recrystallized into small neoblast. |
| Clinopyroxene | 45.7 | 54.0 | 0.5-2.0 | | Subhedral-anhedral | Replaced by amphibole. |
| Spinel Fe-Ti oxide | 15.0 | 15.3 | 0.5-1.5 | | Anhedral | Having highly irregular shape. |
| Pyroxene | 6.4 | 9.7 | 1.0-4.0 | | Subhedral-anhedral | Inverted pigeonite or opx, low Ca. Opx having exsolved blebs of cpx. It intergrows with opaque mineral. Also occurs as patches in cpx. |
| Brown amphibole | 0.3 | 0.3 | 0.1-0.2 | | Anhedral | Replacing cpx, commonly accompanied by opx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | | Filling crack in cpx. |
| Actinolite | 6.3 | Cpx | Replacing cpx from rim and along cracks |
| Hornblende | 6.3 | Cpx | Brown-green. Replacing cpx, veining plag. |

**COMMENTS:** If present, ol is less than 1%. Some opaques in cpx are euhedral to subhedral. "Primary amphibole" is reddish-brown. Low Ca pyroxene and opaque show symplectic intergrowth.
Percentages based on 1500 points.

| | | |
|---|---|---|
| Plagioclase | Primary | 17.3 |
| | Metamorphic | 2.8 |
| Zoisite | | 0.2 |
| Clinopyroxene | | 22.2 |
| | Replaced by amphibole | 18.8 |
| Orthopyroxene | | 4.3 |
| | Replaced by amphibole | 0.3 |
| Blue-green amphibole | | 2.4 |
| Brown amphibole | | 1.9 |
| Actinolite | | 8.1 |
| Opaques, sulfides | | 20.4 |
| Sphene | | 0.8 |

## THIN SECTION DESCRIPTION

**118-735B-23R-4 (Piece 5, 83-86 cm)**

**ROCK NAME:** Aphyric basalt

**WHERE SAMPLED:**

**TEXTURE:** Aphyric, intersertal

**GRAIN SIZE:** Fine

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 50 | 50 | 0.01-0.8 | | Lath-shaped, subhedral | |
| Clinopyroxene | 27 | 42 | 0.05-0.3 | | Anhedral | |
| Olivine | 0 | 5 | 0.15-0.2 | | Skeletal | Totally replaced by talc. |
| Magnetite | 3 | 3 | 0.02-0.07 | | Equant to elongate, skeletal | |
| Cr-Spinel | Tr | | 0.2 | | Anhedral | Xenocryst: has black rims. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 15 | Cpx and mesostasis | Smectite (?) replacing cpx, possibly mesostasis and rimming replaced ol. |
| Talc | 5 | Ol | May be smectite rather than talc. |

## THIN SECTION DESCRIPTION

**118-735B-23R-4 (Piece 9B, 120-122 cm)**

**ROCK NAME:** Aphyric basalt
**WHERE SAMPLED:**
**TEXTURE:** Aphyric, intersertal
**GRAIN SIZE:** Fine
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 51.0 | 50 | 0.05-0.95 | | Subhedral | Lath-shaped, one microphenocryst observed. |
| Clinopyroxene | 24.4 | 41 | 0.1-0.3 | | Anhedral | Slightly replaced by clays and/or chlorite. |
| Olivine | — | 5 | 0.1-0.3 | | Anhedral | Totally replaced. |
| Magnetite | 3.3 | 4 | 0.01-0.13 | | Equant to elongate and skeletal | Partially altered(?). Grainy texture (sphene?). |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 16.0 | Cpx and mesostasis | Some may be chlorite, up to 50% of material identified as clay. |
| Talc | 5.3 | Ol | Some may be clays. |

**COMMENTS:** Possibly actinolite overgrowths on cpx in more altered areas.

## THIN SECTION DESCRIPTION

**118-735B-23R-5 (Piece 3, 21-24 cm)**

**ROCK NAME:** Aphyric basalt
**WHERE SAMPLED:** Contact between gabbro and basalt
**TEXTURE:** Aphyric, glassy
**GRAIN SIZE:**
**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PHENOCRYSTS | | | | | | |
| Olivine | 1 | 4 | 0.1-0.5 | | Euhedral, hopper | Microphenocryst. Partially replaced by chlorite or clay. Ol is preserved in glassy chilled margin. |
| Plagioclase | 12 | 12 | 0.1-1.0 | | Euhedral, hollow | Microphenocryst, commonly intergrown with ol and cpx. |
| Spinel | Tr | Tr | 0.15 | Chromian | Subhedral | Brown, chromian spinel rimmed by magnetite. Rounded. |
| GROUNDMASS | | | | | | |
| Glass | 7 | 7 | | | | Devitrified. In chilled zone, 1-2 mm thick. Dark brown. |
| Plagioclase | 77 | 77 | <0.1 | | Anhedral | Too fine to distinguish. |
| Olivine | | | <0.1 | | Anhedral | |
| Opaques | | | 5μm | | Anhedral | |
| Clinopyroxene | | | <20μm | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | <3 | Ol | Pale green. |
| Chlorite | <1 | Ol | Colorless. |

**COMMENTS:** Ol commonly shows hollow or hopper shapes, indicating rapid cooling. This implies that the gabbro was not so hot when the basalt was intruded into it.
No reaction is observed between minerals of the gabbro, such as amphibole, plag, and cpx.

## THIN SECTION DESCRIPTION

**118-735B-23R-5 (Piece 3, 21-24 cm)**

**ROCK NAME:** Olivine-bearing gabbro intruded by basalt

**WHERE SAMPLED:** Contact between gabbro and basalt

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** 0.5-5.0 mm

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.5 | 4 | 0.5-6.0 | | Anhedral | Core is altered into tremolite and magnetite, rim is altered into actinolite and talc or chlorite. Core is also replaced by clay. |
| Plagioclase | 65 | 70 | 0.5-5.0 | | Anhedral | Partly recrystallized, veined by albite, amphibole and chlorite. |
| Clinopyroxene | 18 | 25 | 1.0-7.0 | | Anhedral | Replaced by brown hbd and further by actinolite. |
| Opaques | 1 | 1 | 0.3-1.0 | | Subhedral | Accompanied by brown hbd, present at the rim of cpx. |
| Orthopyroxene | Tr | Tr | 0.1 | | | Exsolution lamellae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.5 | Ol | Yellowish-brown. |
| Chlorite | 1 | Ol, plag | Replacing rim of ol and veined plag. |
| Albite | 2 | Plag | Veined plag. |
| Actinolite | 5 | Ol vein in plag | |
| Brown Hornblende | 2 | Cpx | Occurs at rim of cpx. |
| Talc | 1 | Ol | |
| Tremolite | 2 | Ol | Replacing core of ol, accompanied by opaque. |
| Fe-Ti Oxide | 1 | Ol | Accompanying tremolite replacing ol core, in cpx as small blebs. |

**COMMENTS:** Plagioclase shows wavy extinction and is partly granulated, indicating weak deformation.

## THIN SECTION DESCRIPTION

**118-735B-24R-2 (Piece 8, 95-97 cm)**

**ROCK NAME:** Ilmenite metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular, porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 10 | 2.0-4.0 | | Anhedral | Partially replaced by colorless amphibole and magnetite. |
| Plagioclase | 10 | 25 | 1.0-4.0 | | Anhedral | |
| Clinopyroxene | 15 | 40 | 2.0-4.0 | | Anhedral | Contains rods and roundish inclusions of opaques. |
| Ilmenite | 22 | 20 | 0.2-0.6 | | Anhedral | Unknown if primary or secondary. Size difficult to estimate because it occurs in granular masses. |
| Orthopyroxene | 2 | 5 | 0.2–0.7 | | Anhedral | As isolated grains replaced by tremolite. Also as inclusions in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 15 | | Neoblasts. |
| Green amphibole | 15 | Cpx, opx | Actinolite-tremolite. |
| Brown amphibole | 10 | Cpx | Patchy in cpx, some larger crystals possibly associated with ilmenite. |
| Colorless amphibole | 9 | Ol | Tremolite. |
| Sulphides | 3 | | Two sulphide intergrowths, pyrrhotite/pyrite. |

**COMMENTS:** Ilmenite occurs as ilmenite-magnetite intergrowths in secondary patches, intergrowths.

## THIN SECTION DESCRIPTION

**118-735B-24R-3 (Piece 3A, 50-52 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyro-granoblastic

**GRAIN SIZE:** Heterogranular

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 45 | 0.01-2.0 | | Euhedral to deformed | Recrystallized into granoblastis with triple junctions. |
| Clinopyroxene | 10 | 50 | <5.0 | | Anhedral | Almost replaced by green amphibole, may contain plag inclusions. |
| Spinel/Magnetite | 3 | 5? | 0.1-0.5 | | Anhedral | Mixture with magnetite, often associated with brown amphibole molded around green amphibole, preferred orientation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite/Tremolite | 5 | Cpx, brown amphibole | Very thin fibers mainly at outer margin of large replaced cpx, colorless to light yellow-green. |
| Hornblende | 32 | Cpx | Green to yellow-brown, pseudomorphs after cpx or filling small veinlets in plag. |
| Plagioclase | 35 | Plag | Granoblasts 0.03-0.5 mm, polygonal-mosaic vein filled with granoblastic plag. |
| Brown amphibole | 1 | Cpx | Often at margins of cpx but not clear if they pre-date or post-date green amphibole. |
| Blue-green amphibole | 2 | Amphibole | Late-stage, replaces green amphibole and blue-green amphibole. |
| Magnetite | 2 | Ilmenite, cpx | Small granules, 0.3 mm, related to cpx and ilmenite. |

**COMMENTS:** In thin section, brown amphibole appears to replace, at many locations, amphibole pseudomorphs after cpx. The foliation is relatively strong without deformation of the grains except for transformation of plag into granoblasts and straining of larger preserved grains.

## THIN SECTION DESCRIPTION

**118-735B-24R-4 (Piece 1A, 1-6 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Massive, orthocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 5 | 0.5-4.0 | | Anhedral | Possibly recrystallized. |
| Plagioclase | 53 | 61 | 2-10 | | Subhedral | Slightly crushed and deformed. |
| Clinopyroxene | 25 | 34 | 1-5 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Mixed with carbonate in fractures in ol. |
| Carbonate | Tr | Ol | Mixed with clay along cracks in ol. |
| Actinolite | 9 | Plag, ol | Actinolite + tremolite. Occurs along grain boundaries. |
| Hornblende | 4 | Cpx | Brown-green and colorless. Occurs in patches in cpx. |
| Hornblende | 5 | Veins, cpx | Veins of green amphibole. |
| Plagioclase | 1 | Plag | Neoblasts. |
| Clinopyroxene | Tr | Cpx | Occurs as patches of neoblasts and in one area, associated with brown hbd. |

**COMMENTS:** Faint metamorphic foliation in alignment of plag neoblasts. Px and ol are recrystallized in one corner of the slide. Most alteration is static replacement of plag + ol along grain boundaries.

## THIN SECTION DESCRIPTION

**118-735B-24R-4 (Piece 1B, 26-28 cm)**

**ROCK NAME:** Olivine bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1.1 | 3 | 1–2 | | Anhedral | Extensively altered. |
| Plagioclase | 51.1 | 53 | 1–4 | | Anhedral | |
| Clinopyroxene | 18.9 | 44 | 1–4 | | Subhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Ol, plag | Occurs along fractures in ol crystals, mixed with talc(?). Also in fractures in plag crystals. |
| Chlorite | Tr | Cpx | Occurs in amphibole clots. |
| Actinolite | 23.9 | Cpx | Aggregates after cpx, along cleavage planes. 4% occurs in veins and in interstices between plag crystals. Possibly overestimated; some dark brown alteration in cpx may be clays, not amphibole. |
| Hornblende | Tr | Cpx | Brown. Rare, in cpx. |
| Opaques | 0.5 | Ol, cpx | Most small grains in cpx pseudomorphs. A few grains 0.1–0.3 mm in size in cpx. |
| Talc | 0.3 | Ol | After ol. |
| Tremolite | 0.6 | Ol | After ol. |

**COMMENTS:** Percentages based on 2000 points.

## THIN SECTION DESCRIPTION

**118-735B-25R-1 (Piece 5, 21-25 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Medium to coarse (<1–4 mm)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 11 | 57 | 0.5–2.0 | | Anhedral, polygonal | Strained. |
| Clinopyroxene | — | 43 | 0.5–4.0 | | Anhedral | Completely replaced by amphibole. |
| Ilmenite | Tr | Tr | <0.5 | | Anhedral | Associated with brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 30 | Cpx | Green to yellowish brown. Pseudomorphs after cpx fibers. 54 mm in size. |
| Plagioclase | 46 | Plag | Polygonal pattern, recrystallized from larger, primary plag crystals. <0.5 mm in size. |
| Brown amphibole | 11 | Cpx | Strong brown to yellow-brown pleochroism. Crystals up to 2.5 mm. Replaced by green amphibole. |
| Blue-green amphibole | 2 | Amphibole | Fibrous intergrowths, 0.2–0.4 mm in size. Replace both green and brown amphiboles. |
| Magnetite | Tr | Ilmenite, cpx | Associated with ilmenite and green amphibole. |

**COMMENTS:** Gabbro was metamorphosed at relatively high temperatures (brown amphibole stage); some brown amphiboles are possibly primary. Retrograde metamorphism to medium grade (green amphibole).
Plag composition is probably related to metamorphic grade (more sodic than primary calcic plag).

## THIN SECTION DESCRIPTION

**118-735B-25R-2 (Piece 1A, 5-7 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic after mesocumulus texture

**GRAIN SIZE:** Medium to coarse (1-5 mm)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 50 | 0.5-2.0 | | Anhedral | Fractures filled with green amphibole. Some granoblasts. |
| Clinopyroxene | 5 | 50 | 1-3 | | Euhedral | Completely replaced by green and blue-green amphibole. |
| Opaques | Tr | Tr | <1 | Ti | Anhedral-euhedral | Possibly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 28 | Cpx | Blue-green to pale brown. Pseudomorphs after cpx. Fibrous variety present in irregular pseudomorphs (after ol?). |
| Plagioclase | 20 | Plag | Granoblasts with polygonal or irregular outlines. |
| Brown amphibole | 2 | Cpx | |
| Blue-green amphibole | 15 | Cpx | Occurs along cracks produced by shear which cut cpx crystals. |
| Magnetite | Tr | Amphibole | Dust in amphibole pseudomorphs. |

**COMMENTS:** Some cpx relicts.
Brown amphibole rimmed by blue-green amphibole.
Generation of blue-green amphibole related to late cracks.
Percentages based on 1522 points.

| | | |
|---|---|---|
| Plagioclase | Primary | 24.5 |
| | Metamorphic | 15.9 |
| Zoisite | | 0.1 |
| Clinopyroxene | Primary | 1.5 |
| | Amphibolitized | 42.2 |
| Amphibole | Brown | 2.3 |
| | Blue-green | 7.0 |
| | Actinolite | 5.3 |
| Opaques | | 0.7 |

## THIN SECTION DESCRIPTION

**118-735B-25R-3 (Piece 2B, 43-48 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 18 | 18 | 5-10 | | Anhedral | |
| Plagioclase | 65 | 65 | 5-15 | | Subhedral-euhedral | |
| Clinopyroxene | 17 | 17 | 3-10 | | Anhedral | Ophitically to subophitically enclosing plag and rarely ol. |
| Orthopyroxene | Tr | Tr | | | | Exsolution in cpx. |
| Opaques | Tr | | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Replacing ol along fractures. |
| Carbonate | Tr | Ol | |
| Tremolite/ actinolite | Tr | Ol | Alteration halo around most crystals. |
| Actinolite | Tr | Plag | In thin cracks in plag. |
| Magnetite | Tr | Ol | |
| Brown amphibole | Tr | Cpx | |

**COMMENTS:** Slide has poor polish and is plucked. Many features of alteration are difficult to determine.

## THIN SECTION DESCRIPTION

**118-735B-25R-3 (Piece 3B, 137-139 cm)**

**ROCK NAME:** Troctolitic gabbro
**WHERE SAMPLED:**
**TEXTURE:** Orthocumulus
**GRAIN SIZE:** Medium (2–4 mm)
**OBSERVER:** HEB

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 8 | 52 | | Rounded | Kinked. Partially replaced by talc, tremolite, and magnetite. |
| Plagioclase | 79 | 87 | 53.5 | | Rounded, subhedral | Strained , deformed twins. |
| Clinopyroxene | 3 | 5 | 54 | | Anhedral, interstitial | Poikilitically enclosing ol or plag. |
| Spinel | Tr(?) | Tr(?) | < < 1 | | Euhedral | Hexagonal crystals close to ol in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 2 | Fractures, cpx | Light blue-green. In late fractures cutting all phases. Also rimming cpx. |
| Talc | 10 | Ol, plag | Coronas around fresh ol or tremolite. |
| Tremolite | 2 | Ol | Prismatic. Intergrowths close to fresh ol cores. |
| Brown amphibole | Tr | Ol, cpx | Attached to ol or cpx. |
| Magnetite | Tr | Ol | Generally <0.01 mm, related to talc replacement. |

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## THIN SECTION DESCRIPTION

**118-735B-25R-3 (Piece 3B, 144-146 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Poikilitic
**GRAIN SIZE:** Medium to coarse
**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9.4 | 16 | 1–2 | | Globular | Elongated. Rare kink bands. |
| Plagioclase | 49.7 | 52 | 1.0–4.5 | An 64 | Subhedral | Igneous twins preserved. |
| Clinopyroxene | 26.4 | 32 | 1–8 | | | Oikocrysts enclosing plag and ol crystals. |
| Spinel | Tr | Tr | | | Anhedral | Opaques. Enclosed in plag and cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite/clay | 0.5 | Ol | [illegible]eenish clay veins occurring with opaques in ol. |
| Tremolite/ actinolite | 5.1 | Ol, plag, cpx | Forms pseudomorphs after ol. |
| Hornblende | 3.3 | Cpx | Two types, brown and blue-green. Invades cpx along cleavage traces. |
| Talc | 5.6 | Ol, plag(?) | Forms reaction coronas around pockets of tremolite (ol pseudomorphs). |
| Opaques | 0.2 | Ol | |

**COMMENTS:** Percentages based on 2000 point counts.
Replacements are static and most of the alteration is concentrated on one end of the thin section.
Distinct fracture set dipping at 25°.
Gabbro is relatively undeformed with many primary twins in plag still preserved and only rare kink bands in ol.
Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-26R-1 (Piece 4B, 62-64 cm)**

**ROCK NAME:** Altered olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 10 | | | Anhedral | Fragments in pseudomorphs. |
| Plagioclase | 45 | 55 | 0.1-6.0 | | Anhedral | Undulose fragments. |
| Clinopyroxene | 5 | 35 | | | Anhedral | Fragments in amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Ol | Dark aggregates associated with ol pseudomorphs. |
| Chlorite | 2 | Cpx | With actinolite. |
| Actinolite | 20 | Cpx | Pale green to green amphibole in fibrous clots after cpx and in veins. |
| Hornblende | 1 | Cpx | Brown patches. |
| Plagioclase | 5 | Plag | Neoblasts. |
| Tremolite | 10 | Ol? | Circular aggregates rimmed by talc. |
| Talc | 5 | Ol | With tremolite. |
| Opaque | 2 | Ol | Small, 0.1mm grains, with ol and cpx pseudomorphs in places. |
| Mica | Tr | Cpx? | Clear to pale tan-yellow, rarely with amphibole. |

**COMMENTS:** High percentage of tremolite-amphibole clots, perhaps after ol; the sample may have been very ol-rich. A 0.5 mm wide granulated zone consisting of fine-grained green amphibole, cuts the sample.

## THIN SECTION DESCRIPTION

**118-735B-26R-1 (Piece 6B, 135-138 cm)**

**ROCK NAME:** Olivine microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Contact between fine-grained and medium-grained gabbros

**GRAIN SIZE:** Fine to medium

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7.4 | 16.4 | 1.0-2.0 | | Globular, anhedral | Sometimes elongated. |
| Plagioclase | 48.5 | 50.6 | 1.0-2.5 | An 63-68 | Subhedral | Rarely up to 4.0 mm. |
| Clinopyroxene | 26.8 | 32.9 | 1.0-2.5 | | Subhedral | Rarely up to 4.0 mm, not oikocrystic. |
| Orthopyroxene | 0.1 | 0.1 | | | Anhedral | Interstitial, rimming ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite/Clay | 0.8 | Ol | Deep brownish-green clay veining and replacing ol (more common in coarser portion). |
| Actinolite/Tremolite | 6.8 | Ol, plag | Intergrown with talc in reaction halos around relict ol. |
| Hornblende | 4.4 | Cpx, veins | Brown and blue-green. |
| Talc | 4.0 | Ol | |
| Opaques | 1.2 | Ol | Blebs and rims around relict ol. |

**COMMENTS:** Contact between medium- and fine-grained gabbro dips at approximately 50°. Both parts are equigranular. Fine-grained part near interface is more highly altered. Three subparallel veins slightly oblique to contact. Igneous lamination defined by mafics is parallel to contact between the two parts.

## THIN SECTION DESCRIPTION

**118-735B-26R-1 (Piece 6B, 135-138 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse to medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8.0 | 20 | 1.0-3.0 | | Anhedral | Partially replaced by tremolite, talc, actinolite and magnetite. |
| Plagioclase | 34.5 | 35 | 2.0-5.0 | | Anhedral | Subhedral where included in cpx. |
| Clinopyroxene | 31.0 | 45 | 2.0-5.0 | | Anhedral | Partially replaced by brown amphibole and actinolite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.8 | Fractures | Replacing ol along fractures. |
| Talc | 6.3 | Ol | |
| Brown amphibole | 0.8 | Cpx, ol | Replacing cpx, often in alteration haloes around ol. |
| Green amphibole | 12.7 | Cpx, ol | Actinolite, replacing cpx and in ol alteration haloes. |
| Colorless amphibole | 3.6 | Ol | Tremolite replacing ol. |
| Magnetite | 2.3 | Ol | |

**COMMENTS:** Transition between gabbro and microgabbro represents primary layering defined by grain size variation. The microgabbro consists of ol, plag and cpx with grain size ranges of 0.2-1.0 mm, 0.2-1.0 mm and 0.2-1.2 mm, respectively.

## THIN SECTION DESCRIPTION

**118-735B-26R-3 (Piece 1E, 94-96 cm)**

**ROCK NAME:** Olivine-bearing gabbro cut by amphibole vein

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2 | 0.5-2.0 | | Euhedral | Totally replaced by calcite, chlorite and tremolite. |
| Plagioclase | 56 | 60 | 0.5-4.0 | | Anhedral | Veined by amphibole, chlorite and albite, showing no granulation or extensive deformation. |
| Clinopyroxene | 30 | 38 | 0.5-3.0 | | Subhedral | Far away from amphibole vein. Replaced by small amount of brown hbd and actinolitic hbd. Actinolite near the vein is totally replaced by green amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 1 | Ol | Replacing core of ol. |
| Chlorite | 4 | Ol, plag | Replacing core of ol, veining plag. |
| Albite | 1 | Plag | Veining plag. |
| Actinolite | 4 | Cpx, plag | Veining plag, replacing cpx. |
| Green hornblende | 1 | Vein, cpx | Slightly brownish. Mainly filling veins where it has 0.5-3.0 mm grain size, subhedral to anhedral. It also totally replaces cpx near vein within 3.0 mm of the vein wall. |
| Tremolite | 1 | Ol | Replacing ol. |
| Brown hornblende | 2 | Cpx | Replacing cpx and replaced by actinolitic amphibole. |
| Fe-Ti oxide | Tr | Ol | Accompanying tremolite. |

## THIN SECTION DESCRIPTION

**118-735B-26R-3 (Piece 1E, 94-96 cm)**

**ROCK NAME:** Partly amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular to granoblastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 60 | 65 | 0.5-1.0 | | Idiomorphic | Main cumulus phase. |
| Clinopyroxene | 25 | 35 | 0.2-3.0 | | Sub-idiomorphic | Partially to completely replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | | In late-stage 1.0 mm thick vein, replacing plag. |
| Chlorite | 3 | Plag, mafics | Grey colors, pseudomorphs after cpx or ol by actinolite. |
| Actinolite/Tremolite | 4 | Chlorite, plag | Fibers replacing chlorite, plag and late-stage veinlet. (small idioblastic cpx prisms). |
| Hornblende | 8 | Cpx | Green, restricted to highly amphibolitized area. Some have a strong bluish tint. This should be compared to other blue-green rims seen elsewhere. |
| Magnetite | Tr | Cpx | Included in amphiboles. |
| Carbonate | Tr | Plag | Intermixed with tremolite. |

**COMMENTS:** Gabbroic section: relatively fresh but px replaced by amphibole, chlorite and tremolite in later stage "upper greenschist facies" (brown). amphibole virtually absent). Amphibolitized area: sheared(?), near equilibrium assemblage, idioblastic grains with straight contacts and triple junctions, plag is fractured and fractures infilled with amphibole.

## THIN SECTION DESCRIPTION

**118-735B-26R-4 (Piece 5, 91-96 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Foliated, orthocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 10 | 1.0-5.0 | | Anhedral | Altered to either talc or smectite. |
| Plagioclase | 65 | 70 | 2.0-10.0 | | Subhedral | Some recrystallized. |
| Clinopyroxene | 3 | 14 | 2.0-10.0 | | Anhedral | Partially altered to amphibole. |
| Orthopyroxene | 1 | 1 | | | | Rims on ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | | Ol | Brown, mixed with smectite. |
| Carbonate | Tr | | Replacement of ol. |
| Chlorite | 1 | Cpx, hbd | Pale green, dark with crossed nicols. |
| Albite | 5 | Plag | Clear veins in plag in crushed zone. |
| Sodic plagioclase | 1 | Cpx | High relief, fine-grained inclusions in amphibole replacements of cpx. Possibly rutile? |
| Actinolite | 10 | Cpx, hbd | Pale green, bladed, associated with chlorite. |
| Hornblende | 5 | Cpx, vein | Pale green-brown, in fractures and replacement. Mixture. |
| Magnetite | 1 | Ol | Tremolite-talc(?) replacement. |
| Talc | 1 | | Replacing ol. |
| Tremolite | 4 | Ol | Bladed. |

**COMMENTS:** Some plag is crushed, altered ol or actinolite, may be slightly deformed. Igneous foliation, numerous amphibole veins. Rock may be slightly deformed with recrystallized plag.

## THIN SECTION DESCRIPTION

**118-735B-27R-1 (Piece 5, 23-25 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Medium

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | - | 38 | 2.0 | | Recrystallized polygonal | All recrystallized into smaller granoblasts, twins still present. |
| Clinopyroxene | Tr | 35 | 5.0 | | Euhedral | |
| Orthopyroxene | Tr | 1-2 | 4.0 | | Anhedral | Relicts of medium relief, parallel extinction, low birefringence px. |
| Opaques | 3 | 5 | 4.0-0.3 | | Anhedral | Partly recrystallized as lamellae or needles surrounded by red-pink clay or chlorite, related to brown amphibole. Preferred orientation. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Opaques | Alteration products of opaques? |
| Carbonate | 1 | | Isolated grains related to cracks and opaques. |
| Chlorite | 5 | Plag, opaques | Blue birefringence color, around ilmenite mixed with red to pink (chlorite and hematite?), probably different compositions. |
| Epidote | 2 | Plag | Colorless, abnormal polarizing colors, anhedral grains. |
| Actinolite/Tremolite | 8 | Amphibole | Coronal reaction around amphibole pseudomorphs, some overgrowths on chlorite. |
| Sphene | 1 | | More or less idioblastic, grains altered to ilmenite and chlorite. |
| Hornblende | 35 | Px oxene | Pseudomorphs after px, green to medium brown. |
| Plagioclase | 35 | Plag | Granoblasts. |
| Brown amphibole | 5 | Pxroxene | As pseudomorphs after px or corona around green-brown amphibole. |
| Blue-green amphibole | 3 | Amphibole | As more or less continuous rims around green-brown amphibole, acicular overgrowth or isolated interstitial patches. |

**COMMENTS:** Complete gradation from middle to high temperature metamorphism to greenschist. Mixture of Fe hydroxides and clay-type mineral surround opaques, typically pink-red in color.

## THIN SECTION DESCRIPTION

**118-735B-27R-1 (Piece 8B, 84-88 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocomulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 5 | 4 | | Anhedral | Some alteration. |
| Plagioclase | 60 | 65 | .5-5 | | Anhedral | |
| Clinopyroxene | 25 | 30 | 2-8 | | Anhedral | Some alteration to amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 11 | Cpx | Veins in pllag. Rimming cpx. Quite extensive in cpx on a fine scale. |
| Hornblende | Tr | Cpx | Brown amphibole in cpx. |
| Opaque | Tr | Ol | Small opaques in ol alteration. |

**COMMENTS:** Thin section cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118-735B-27R-2 (Piece 1A, 4-6 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 40 | 0.02-1.00 | | Polygonal | Recrystallized into smaller granoblasts; not equilibrated. |
| Clinopyroxene | — | 57 | 0.3-2.0 | | Anhedral | Completely recrystallized. |
| Ilmenite | Tr(?) | 3 | | | Irregular | Possibly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Sphene | 1 | Opaques | Idioblastic. Red staining by hematite. Sometimes amphibole + hematite. |
| Hornblende | 10 | Cpx, amphibole | Idioblastic. Strongly pleochroic. Concentrated along cracks or small shear zones. Crystallization extends no more than 4 mm from crack. |
| Plagioclase | 35 | Plag | Granoblasts with irregular shapes and contacts. |
| Hematite | Tr | Amphibole | Rose-red color. Close to opaque grains in the brown amphibole zone. |
| Amphibole | 46 | Cpx | Blue-green. Light yellowish to brown-green pleochroism. Pseudomorphs. Clearly predates brown amphibole in this section. |
| Opaques | 3 | Oxides | Irregular. Associated with amphiboles. Possibly of hydrothermal origin. |

**COMMENTS:** Recrystallization of plag and amphibolitization of cpx show that the rock was not equilibrated. Sphene-opaque-hematite-amphibole assemblage shows breakdown of small existing opaques. Cracks provided access to circulation fluids which generated the brown amphiboles after blue-green amphibole (which earlier replaced cpx).

## THIN SECTION DESCRIPTION

**118-735B-27R-3 (Piece 1B, 32-34 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate, granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 5 | 2-4 | | Anhedral | Kink-banded. Replaced by talc/tremolite. |
| Plagioclase | 60 | 60 | 0.1-4.0 | | Anhedral | Undulose extinction. Minor deformation. |
| Clinopyroxene | 15 | 35 | 1.5-6.0 | | Anhedral | Interstitial to cpx. Some fine-grained cpx-cpx intergrowths at grain boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 20 | Cpx | Patchy to well-crystallized. 0.1-3.0 mm grains after cpx. Also in veins through plag. |
| Hornblende | Tr | Cpx | Brown amphibole in cpx. |
| Tremolite | 1 | Ol | |
| Talc | Tr | Ol | |
| Oxides | 1 | Ol | |

**COMMENTS:** Thin section is from the end of a minicore. Slightly deformed. Granular cpx "intergrowths" possibly initial stages of grain boundary granulation.

## THIN SECTION DESCRIPTION

## 118-735B-27R-3 (Piece 10, 73-81 cm)

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:** Coarse portion above graded layer

**TEXTURE:** Poikilitic to anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 0.4–5.0 | | Anhedral-euhedral | Having sub-grain boundaries (recrystallized and polygonized). Altered to tremolite/actinolite and reacted with plag. |
| Plagioclase | 35 | 50 | 0.4–10.0 | | Anhedral-subhedral | Most crystals are anhedral. |
| Clinopyroxene | 34 | 37 | 1–40 | | Anhedral | The largest oikocryst is more than 40 mm across. |
| Oxide | 1 | 1 | 0.1–0.5 | Fe-Ti | Anhedral-euhedral | Inclusions in cpx, locally rimming ol. |
| Hornblende | 1 | 1 | 0.1–0.5 | | Anhedral | Brown. Locally rimming and replacing cpx replaced by actinolite. |
| Orthopyroxene | Tr | 1 | 0.1–0.3 | | Anhedral | Inclusions or exsolution lamellae in cpx. Also rarely rimming ol. Locally rimming cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Brownish green. Filling cracks in ol. |
| Chlorite | 1 | Plag, ol | Reaction product occurring between plag and tremolite + oxide, after ol. |
| Actinolite/ tremolite | 2 | Ol, cpx, opx | Replacing ol, brown amphibble, and cpx at plag-plag grain boundaries. Also in veins in plag. |
| Hornblende | 1 | Cpx | Brown-green. Replacement rims around cpx. |
| Mica | 3 | Plag | Replacing plag (not ol). Always occurs between tremolite/actinolite, after ol and plag. |
| Oxides | 1 | Ol | Fe-Ti oxides. Occurs with tremolite/actinolite. |

**COMMENTS:** Cpx oikocrysts up to 4 cm.

## THIN SECTION DESCRIPTION

## 118-735B-28R-1 (Piece 6, 57-60 cm)

**ROCK NAME:** Mylonitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic, porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 83 | 0.5-4.2 | | | Strained and recrystallized. |
| Clinopyroxene | 5 | 15 | 1.0-4.0 | | | Strongly replaced by amphibloe or crushed before replacement. |
| Fe-Ti | 2 | 2 | 1.0-4.0 | | | Streaks elongated in foliation. Partially replaced by sphene. |
| Brown hornblende | Tr | Tr | 0.5 | | | Magmatic? Rims around oxides or close to cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Epidote | 5 | Plag | Hexagonal or tail-shaped, rotated into foliation planes in plagioclese-rich area of section. |
| Sphene | 2 | Opaques | Irregular, around opaques, associated with epidote. |
| Hornblende | | Px | Colorless to light brown, pseudomorphs after cpx. |
| Plagioclase | 68 | Plag | Grano-neoblasts. 0.5mm. |
| Brown amphibole | 8 | Px, amphibole | Dark brown to yellow brown, coronitic replacement of pyroxene or hornblende pseudomorphs, also associated with opaques. |
| Zirion | Tr | | Euhedral. |
| Blue-green amphibole | 2 | Amphibole | Lining the brown amph or the amph pseudomorphs. |
| Hematite | Tr | Opaques | Rose-red associated with amph (?). |

**COMMENTS:** Visual pattern of deformation, recrystallization, high temperature. Brown amph post-dating light brown amph and hematite. Late-stage, blue-green amph. Epidote development. Oxides can be remobilized at high temperature stage.

## THIN SECTION DESCRIPTION

**118-735B-28R-2 (Piece 1B, 12-14 cm)**

**ROCK NAME:** Weakly deformed olivine-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Fine to medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 3-5 | 0.4-1.5 | | Polygonal-anhedral | Partly replaced. |
| Plagioclase | 50 | 60 | 0.8-5.0 | | Subhedral-anhedral | Well-marked subgrain boundaries, locally recrystallized (micro-shears and often kinked). |
| Clinopyroxene | 25 | 30 | 0.8-6.0 | | Anhedral | Replaced by brown- and then green amphibole. |
| Fe-Ti oxides | 3 | 3 | 0.2-1.2 | | Anhedral-subhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING | COMMENTS | COMMENTS |
|---|---|---|---|---|
| Clays | <1 | Ol | | Unstrained clay in core of ol, associated with oxides. |
| Actinolite | 1 | Plag, ol | | |
| Green hornblende | 7 | Brown hbd, cpx | | |
| Plagioclase | 10 | Plag | | Recrystallized grains in micro-shears. |
| Oxides | 1 | Ol | | Associated with clays. |
| Talc | <1 | Ol | | |
| Tremolite | 1 | Ol | | |
| Orthopyroxene | Tr | Ol? | | Filling vein cross-cutting ol. |

**COMMENTS:** Deformation extremely ? , seems to occur prior to hydrate replacement. A vein of what appears to be hydrothermal opx crosscuts the ol.

## THIN SECTION DESCRIPTION

**118-735B-28R-2 (Piece 6, 114-116 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0 | 5 | 5.0 | | Anhedral | Pseudomorphed by talc/tremolite. |
| Plagioclase | 60 | 70 | 1.0-4.0 | | Anhedral | Undulose, some recrystallization. |
| Clinopyroxene | 12 | 25 | 2.0-5.0 | | Anhedral | Interstitial to plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Small dark brown aggregates after ol. |
| Actinolite | 18 | Cpx | Light green, fibrous and patchy amphibole after cpx, also filling veins in plag. |
| Plagioclase | 4 | Plag | Small neoblasts on grain margins. |
| Talc | 1 | Ol | |
| Tremolite | 4 | Ol | |
| Opaque | Tr | Ol | Small grains in ol pseudomorphs (sulphides?). |
| Carbonate | <1 | Ol | Associated with dark clay minerals. |

**COMMENTS:**

## THIN SECTION DESCRIPTION

**118-735B-28R-3 (Piece 4, 63-69 cm)**

**ROCK NAME:** Norite

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.1 | 0.1 | | | | Relict of intergrown with pigeonite, exhibiting magmatic reaction relationship. |
| Plagioclase | 58.4 | 59.2 | | | | |
| Clinopyroxene | 2.0 | 2.5 | | | | |
| Brown hornblende | 0.2 | 0.2 | | | | |
| Inverted pigeonite | 29.9 | 37.5 | 5.0-15.0 | | | Now hypersthene with cpx exsolution blebs and lamellae of cpx. Some grains exhibit well-known herringbone texture. |
| Fe-Ti oxide | 0.4 | 0.5 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.4 | | |
| Epidote | 0.8 | Plag | Both zoisite (with birds-eye blue interference color) and epidote are present. Associated with colorless amphibole at grain boundary between pigeonite and plag. Also occurs in veins and blebs in plag. |
| Actinolite/Tremolite | 5.1 | | |
| Sphene | 0.1 | Fe-Ti oxide | Forms mesh with Fe-Ti oxide that it replaces. |
| Brown hornblende | 2.6 | Pigeonite, cpx | Some brown hbd appears to be primary (reported above) but most is secondary. |

**COMMENTS:** Alteration products of pigeonite and cpx not easily differentiated, so estimated original pigeonite/cpx ratio is the same as the present ratio. Original proportion of brown hbd is also poorly known. Percentages based on 2000 points.

## THIN SECTION DESCRIPTION

**118-735B-28R-4 (Piece 18,141-144 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Medium

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 40 | 0.02-1.5 | | Polygonal, irregular | Possibly all recrystallized and reequilibrated plag even if twins are present. |
| Clinopyroxene | 10 | 55 | 1.0-4.0 | | Anhedral-subhedral | |
| Spinel | Tr | 5 | 0.1 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | | In cracks with blue-green amphibole. |
| Hornblende | 33 | Pyroxene | Green to light brown pseudomorphs after pyroxene. |
| Plagioclase | 35 | Plag | Polygonal neoblasts. |
| Brown amphibole | 10 | Pyroxene, amphibole | Filling cracks, also associated with opaques. |
| Blue-green amphibole | 2 | Pyroxene, cracks | Small amounts. Filled cracks are cut by dark brown amphibole-filled cracks. Nearly continuous rim around pyroxene. |
| Opaques | 5 | Intergrown in spaces, fractures | Seem introduced along some fractures, then brown amphibole, magnetite and sulphide. |
| Prehnite | Tr | Plag | Fibro-radiated crystals, light green, replacing edge of plag. |

**COMMENTS:** Some pattern of deformation and metamorphism. Opaques appear to be secondary.

## THIN SECTION DESCRIPTION

**118-735B-29R-1 (Piece 1G, 88-92 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Sheared

**GRAIN SIZE:** Fine to medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3(?) | (?) | | | Replaced by tremolite/actinolite, clays, and opaques. |
| Plagioclase | 44 | 64 | 2-6 | | | Porphyroclasts. Fractured, kinked, and recrystallized into very small grains. |
| Clinopyroxene | 1 | 33 | 5 | | Anhedral | Extensively replaced by green amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol(?) | Occurs with opaques. |
| Albite | 2 | Plag | |
| Actinolite | ≤2 | Ol(?), plag | Occurs with tremolite and in plag grains. |
| Hornblende | 32 | Cpx | Large, green porphyroclasts and recrystallized grains. Kinked and fractured. |
| Plagioclase | 16 | Plag | Very small (540 μm) polygonal grains. |
| Tremolite | 1 | Ol(?) | Occurs with actinolite. |
| Opaques | <1 | Ol(?) | Occurs with clay. Patchy ilmenite. Tiny magnetite crystals in clear amphibole at one side of the thin section. |

**COMMENTS:** The deformation produced shear zones and a rough foliation (both visible in sample), both affecting the green amphibole (hydrothermal material?).

## THIN SECTION DESCRIPTION

**118-735B-29R-2 (Piece 1D, 46-48 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 5 | 0.8-2.0 | | Anhedral | Rimmed by tremolite. |
| Plagioclase | 55 | 60 | 0.5-4.0 | | Subhedral-anhedral | Undulose extinction. Slightly deformed. |
| Clinopyroxene | 22 | 35 | 1-4 | | Anhedral | Interstitial to subophitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | In ol pseudomoprhs near vein. |
| Actinolite | 13 | Cpx | Patchy to granular aggregates after cpx and in veins. Pale green to blue-green. |
| Plagioclase | 5 | Plag | Neoblasts, granules <0.1 mm, in veined zone. |
| Tremolite | 1 | Ol | Aggregates rimming ol. |
| Talc | Tr | Ol | |
| Oxides | Tr | Ol | Magnetite in amphibole reaction zone next to ol. |

**COMMENTS:** Thin section cut from the end of a minicore.
Sample cut by an amphibole vein, 2-3 mm wide. Ol, cpx replacement is most complete there. Plag granulation is confined to this region.

## THIN SECTION DESCRIPTION

**118-735B-29R-3 (Piece 14C, 129-131 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulus

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 8 | 10 | | Anhedral | Some sub-grain boundaries. Replacement corona with talc, mica and tremolite. |
| Plagioclase | 58 | 69 | 10-20 | | Anhedral-euhedral | Locally kinked crystals, crushed and albitized. |
| Clinopyroxene | 13 | 23 | 10 | | Anhedral subhedral | Partially replaced by green amphibole. |
| Hornblende | <1 | | | | | Brown. Rims of cpx, replaced by green hbd. |
| Orthopyroxene | <1 | <1 | | | | Occurs in inner rim of replacement corona of ol. Euhedral small grains. No distinct grain boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Occurs in the core of ol grains. |
| Carbonate | <1 | Ol | |
| Chlorite | <1 | Plag | Occurs along the contact between plag and ol replacement corona. |
| Albite | 10 | Plag | Crushed crystals. |
| Actinolite | 1 | Ol, plag | In outer rim of replacement corona of ol. |
| Hornblende | 10 | Cpx, veins, Brown hbd | Green. Sheared. |
| Mica | Tr | Ol | In replacement corona, frequently with opx as inner rim. |
| Talc | Tr | Ol | In replacement corona, frequently with opx as inner rim. |
| Tremolite | 1 | Ol | In replacement corona, frequently with opx as inner rim. |

**COMMENTS:** Question: is the opx rimming the ol a replacement product (secondary), or a late magmatic phase? Large oriented thin section.

## THIN SECTION DESCRIPTION

**118-735B-29R-4 (Piece 1B, 19-24 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 48 | 59 | 0.2-4.0 | | Anhedral-euhedral | Partially in cpx. Very undulose extinction. |
| Clinopyroxene | 14 | 41 | 1-4 | | Anhedral | Interstitial. Rarely poikilitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1(?) | Plag | Dusty fractures and boundaries. |
| Actinolite | 27 | Cpx | Also in veins and fractures throughout. Good pale green to green amphibole. Well crystallized. Probably actinolitic hornblende. |
| Hornblende | 5 | Cpx | Brown amphibole. |
| Plagioclase | 5 | Plag | <0.2 mm neoblasts. |
| Spinel | Tr | Cpx | In cpx replacements. |

**COMMENTS:** Some deformation. Plag is bent with undulose extinction, and in part, granulated and recrystallized. Amphibole in fractures cut the plag crystals, but in places in fine recrystallized aggregates. Syn-to post-deformational. Very undulose amphibole fragments in places.

## THIN SECTION DESCRIPTION

**118-735B-30R-1 (Piece 18, 135-138 cm)**

**ROCK NAME:** Olivine-bearing metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3(?) | 0.5–4.0 | | Euhedral | Completely replaced by chlorite + tremolite/actinolite. Rimmed by actinolite. |
| Plagioclase | 52 | 58 | 0.3–4.0 | | Subhedral–euhedral | Cut by many small veins of amphibole and replaced by chlorite. |
| Clinopyroxene | 27 | 37 | 0.2–4.0 | | Subhedral | Replaced by brown-green amphibole + actinolite. Some crystals are perfectly replaced by amphibole. |
| Oxides | 2 | 2 | 0.2–0.4 | Fe-Ti | Anhedral | Occur at the margins of or as inclusions in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Vein | Veins in plag. |
| Chlorite | 5 | Ol, plag | Replacing ol and plag. |
| Albite | 1 | Plag | Veins in plag. |
| Actinolite/ tremolite | 10 | Ol, cpx | 0.1–0.4 mm long lath of tremolite replacing ol. Accompanied by chlorite. Pale green actinolite rimming tremolite after ol and cpx. |
| Hornblende | 3 | Cpx, vein | Brown-green. Replacing cpx. Brown hbd locally rims and replaces cores of cpx. Green hbd (actinolitic) replaces cpx rims commonly, but rarely replaces entire grain. Green hbd also occurs in veins in plag. |

**COMMENTS:** Foliation possibly magmatic in origin. Some grain size variation showing layering.

## THIN SECTION DESCRIPTION

**118-735B-30R-2 (Piece 13D, 120-122 cm)**

**ROCK NAME:** Plagioclase-rich portion of amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granoblastic

**GRAIN SIZE:** Originally coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 90 | 0.01–0.80 | | Irregular | Recrystallized. Originally large crystals recrystallized into granoblasts. |
| Clinopyroxene | Tr | 10 | 1–6 | | Subhedral | Almost completely replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Near cracks. Brown dust in plag. |
| Epidote | Tr | Plag | Blue birefringence colors close to a crack. Replacing plag in strained areas. |
| Actinolite | 2 | Cpx | Fibers associated with epidote. Also replacing cpx and filling veinlets, and as amphibole pseudomorphs. |
| Hornblende | 7 | Cpx, plag | Blue-green to pale yellow-brown. Pseudomorphs after cpx and filling veinlets in plag. |
| Plagioclase | 90 | Plag | Granoblasts with irregular contacts. Represents nonequlibrium. |
| Amphibole | 1 | Cpx | Brown. Related to cracks. Replacing pseudomorphs. |
| Magnetite | Tr | Cpx | Minute grains, <0.07 mm, in amphibole. |

**COMMENTS:** Possibly from a vein in the gabbro itself.
There is some lining of blue amphibole around actinolite pseudomorphs after cpx.

## THIN SECTION DESCRIPTION

**118-735B-30R-3 (Piece 6B, 137-139 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidioblastic

**GRAIN SIZE:** Coarse (average 5 mm)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 10 | <1 | | Polygonal | Highly strained and recrystallized. |
| Clinopyroxene | 10 | 85 | 0.4–5.0 | | | Slightly deformed. Largely replaced by several types of amphiboles. |
| Oxides | — | 5 | | | Anhedral-subhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | <1 | Cpx | Associated with opaques. Contain needles of green amphibole (actinolite). |
| Epidote | <1 | Plag, veins | Blue-yellow birefringence color. Idioblastic crystals replacing plag and filling cracks. |
| Hornblende | 60 | Cpx | Green to pale brown pseudomorphs after cpx. Darker green at the rims or in cracks. |
| Plagioclase | 10 | Plag | Granoblasts recrystallized into polygons. |
| Amphibole | 15 | Amphibole | Brown. As rims around amphibole pseudomorphs or near cracks. |
| Clinopyroxene | Tr | Cpx | Granoblasts or neoblasts around large cpx phenocrysts. |
| Hematite | 2 | Oxides | Deposited along cpx cleavages. Also replacing amphibole. |
| Magnetite/ ilmenite | 3 | Oxides | Lamellae of ilmenite or magnetite in silicate or in cracks. |
| Sulfides | <1 | | Pyrite in cleavage and cracks of cpx, magnetite, ilmenite, and plag. |

**COMMENTS:** Late cracks are filled with secondary carbonate + opaques + actinolite. Brown amphibole is late since it is found in or near cracks and as rims around amphibole pseudomorphs.

## THIN SECTION DESCRIPTION

**118-735B-30R-4 (Piece 2D, 14-16 cm)**

**ROCK NAME:** Amphibolitized olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 15(?) | | | Anhedral | Original grains up to 4 mm. |
| Plagioclase | 58 | 58 | 0.2–4.0 | | Anhedral | Slight deformation: undulose extinction, spindle twins |
| Clinopyroxene | 9 | 27 | 1–2 | | Anhedral | Extensive amphibolitization. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | In ol pseudomorphs. Dark brown. |
| Chlorite | 4 | Ol, cpx | Outside of tremolite and actinolite aggregates. |
| Actinolite | 14 | Cpx, veins | Patchy and fibrous aggregates after cpx. Also in veins. |
| Hornblende | Tr | Cpx | Brown. |
| Tremolite | 7 | Ol | Fibrous aggregates. |
| Talc | 2 | Ol | Mixed with tremolite or outside tremolite zone. |
| Oxides | 1 | Ol | Magnetite in reaction zones replacing ol. |
| Sulfides | Tr | | Disseminated pyrite, partially attacked by solutions inducing alteration. |

**COMMENTS:** Thin section taken from the end of a minicore.
Amphibole in one large vein (1 mm) is quite blue-green. Ol pseudomorphs are tremolite to talc, tremolite to chlorite zoned; clays at center and along fractures of remnant ol.

## THIN SECTION DESCRIPTION

**118-735B-30R-4 (Piece 4, 58-64 cm)**

**ROCK NAME:** Olivine meta gabbro

**WHERE SAMPLED:**

**TEXTURE:** Heteradcumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 4 | 1-3 | | Rounded | Included in plag, rarely in cpx. |
| Plagioclase | 15 | 66 | 1-10 | | Rounded | Included in large cpx oikocrysts. Recrystallized into neoblasts. |
| Clinopyroxene | 20 | 30 | 2-12 | | Anhedral | Large oikocrysts. |
| Amphibole | Tr(?) | Tr | <0.2 | | Anhedral | Brown. Very small patches at the edge of large cpx crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Yellow-green smectite. Sometimes developing mesh texture in altered ol. |
| Carbonate | Tr | Ol | Associated with smectite. |
| Chlorite | 1 | Ol | Chlorite + magnetite. Brown interference colors, colorless. Replaced by actinolite. Occurs at outer rim of ol, close to plag. |
| Hornblende | 8 | Cpx | Green to green-brown. Pseudomorphs after cpx. |
| Plagioclase | 51 | Plag | Granoblasts with irregular grain boundaries. |
| Tremolite | 2 | Ol | Center of ancient ol; replaces all grains. |
| Talc | Tr | Ol | Outer part of replaced ol, close to plag crystals. |
| Amphibole | 2 | Amphibole | Blue-green. Diffuse rimming amphibole pseudomorphs. Also along cracks cutting large cpx in fractures. |
| Magnetite | 1 | Ol | Occurs with chlorite. Small granules in association with alteration products of ol. |

**COMMENTS:** Deformation concentrated in small shear zones.
Cpx replaced by brown amphibole, green amphibole, blue-green amphibole, from core to rim.
Ol replaced by tremolite + talc + chlorite + magnetite.

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## THIN SECTION DESCRIPTION

**118-735B -30R-4 (Piece 7, 131-138 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | (?) | | | | |
| Plagioclase | 43 | 62 | 1-3 | | | Pervasively albitized. |
| Clinopyroxene | — | 33 | 1-5 | | | Amphibolitized. |
| Orthopyroxene | — | 5 | (?) | | | Possibly ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Replacing plag. Colorless. Possibly fine-grained amphibole. |
| Chlorite | Tr | Opx(?) | Dark patches in cores of pseudomorphs. |
| Albite | 15 | Plag | In vein with epidote. Rims on plag. |
| Epidote | 7 | Veins | Blue interference colors. Twinned euhedral crystals in vein. |
| Actinolite | 5 | Opx(?), plag | Tremolite pseudomorphs after opx(?). Also pale green crystals replacing plag. |
| Hornblende | 20 | Veins, cpx | Green pleochroic rims on cpx. Also in vein. |
| Hornblende | 10 | Cpx | Pale cores of cpx pseudomorphs. |
| Sulfides | Tr | Plag, opx(?) | Pyrite. In tremolite/magnetite reaction. |
| Oxides | Tr | Ol | Zones after ol. |

**COMMENTS:** Pseudomorphs of a mafic phase are dark chlorite surrounded by tremoite. Assume this to be opx or ol.

## THIN SECTION DESCRIPTION

**118-735B-30R-5 (Piece 6A, 91-93 cm)**

**ROCK NAME:** Partially amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 70 | <0.1-6.0 | | Anhedral | Porphyroclasts highly strained. Former grains were coarse coarser. |
| Clinopyroxene | 15 | 30 | 0.2-3.0 | | Anhedral | Small grains. |
| Ilmenite | Tr | Tr | 1 | | Anhedral | Interstitial phases, partially secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol(?) | Yellow-brown smectite. |
| Plagioclase | 60 | Plag | Neoblasts and granoblasts. |
| Amphibole | 2 | Cpx | Brown. Strongly pleochroic. Granoblasts at the edge of cpx or in cracks in plag. |
| Tremolite | 7 | Cpx | Partially replacing the rim of cpx grain. Radially crystallized. |
| Clinopyroxene | 5 | Cpx | Small, recrystallized neoblasts close to phenocrysts. |
| Ilmenite | Tr | Cracks | Straight, open fissure also filled in parallel structures by strongly pleochroic brown amphibole. |
| Amphibole | 1 | Amphibole | Grass-green. As rims around cpx and related tremolite. |
| Magnetite | Tr | Ol | Occurs with smectite. |

**COMMENTS:** Deformed and strained gabbro: foliation well developed and plag is recrystallized.
Possibly ol originally present, but as accessory phase (lense of smectite).
Modal estimation does take into account the plag-rich coarse-grained part of the thin section.

## THIN SECTION DESCRIPTION

**118-735B-30R-5 (Piece 7,110-115 cm)**

**ROCK NAME:** Olivine gabbro cut by apegmatitic olivine gabbro

**WHERE SAMPLED:**

**GRAIN SIZE:** Coarse to fine

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7 | 10 | 1.0-3.0 | | Rounded | Subgrain boundaries, polygons with straight edges, deformation lamellae. |
| Plagioclase | 52 | 60 | 0.2-5.0 | | Anhedral-euhedral | Irregular grain-sized mosaic. |
| Clinopyroxene | 25 | 30 | 1.0-5.0 | | Anhedral | Fresh islets, surrounded by dirty brown amphibole. |
| Spinel (chromite?) | <1 | <1 | 0.1 | | Idiomorphic | Possibly magnetite, surrounded by brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol, cracks | Yellow green. |
| Hornblende | 4 | Cpx | Dirty brown, pseudomorphs. |
| Plagioclase | 5 | Primary plag | Recrystallized, non-equilibrated mosaic (irregular edges). |
| Tremolite | 2 | Ol | Colorless, needle-like grains in every direction. |
| Blue-green amphibole | 1 | Ol, cpx | As rims around mafic minerals or in late-stage open cracks. |
| Brown amphibole | 2 | Ol, opx | Associated with opaques, strongly pleochroic patches. |
| Magnetite | 1 | Ol | Seam around or filling cracks in ol. |

**COMMENTS:** Pegmatoid ol-poor gabbro invading ol gabbro (islets of former gabbro). High temperature grademetamorphism present and late-stage, low grade assemblage.

## THIN SECTION DESCRIPTION

**118-735B-31R-2 (Piece 2B, 40-45 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1.8 | 5.3 | 1.0-8.0 | | Subhedral | |
| Plagioclase | 53.3 | 54.0 | 1.0-10.0 | | Subhedral—anhedral | |
| Clinopyroxene | 36.4 | 40.6 | 1.0-15.0 | | Subhedral | Preferred subvertical orientation. |
| Sulphide | Tr | Tr | | | Anhedral | Found at margins of primary cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.2 | Ol | Veining ol. |
| Chlorite | 0.3 | Plag | Occurs at outer rim of reaction corona around ol pseudomorph. |
| Actinolite/Tremolite | 3.2 | Ol | |
| Hornblende | 4.2 | Cpx | Forms rims around cpx up to 2.0 mm wide. Also found in veins. |
| Magnetite | 0.1 | Ol, cpx | Occurs as blebs in cpx, late stage exsolution and/or alteration. In association with tremolite replacing ol. |
| Carbonate | Tr | Ol | One carbonate pseudomorph after ol, partly enclosed in cpx. |
| Micaceous mineral | 0.4 | Plag | Possibly margarite; highly birefringent like talc. Occurs in association with tremolite, pseudomorphs after ol where ol borders plag, clearly replacing plag. |

**COMMENTS:** 1-2 mm wide cataclastic zone dipping at approximately 55°, filled with granular plag and cpx; clearly provided conduit for fluids. Subhorizontal amphibole veins branch out from this zone.

## THIN SECTION DESCRIPTION

**118-735B-31R-2 (Piece 3C, 77-81 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic to porphyroclastic

**GRAIN SIZE:** Coarse to fine where granulated

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 50 | 0.4-4.0 | | Anhedral | Porphyroclasts. |
| Clinopyroxene | 5 | 42 | 3.0-7.0 | | Anhedral | Almost totally replaced by light brown amphibole. |
| Fe-Ti oxide | 8 | 8 | < 1.0 | | Anhedral | Occurs as large equant grains and as thin strings lining grain boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 30 | Plag | Neoblasts. |
| Brown amphibole | 21 | Cpx, veins | Replaces cpx and surrounds Fe-Ti oxides, fills veins. |
| Green amphibole | 15 | Cpx | Actinolite. |
| Colorless amphibole | 1 | Cpx | |

**COMMENTS:** One side of the slide is more deformed than the other and contains more opaque minerals. This side, with abundant Fe-Ti oxides, has cpx porphyroclasts which are rounded, while on the less deformed side lacking Fe-Ti oxides, the cpx replaced by amphibole tends to be connected to numerous amphibole veins creating a network appearance with the original cpx as "nodes" along the network. Cpx is replaced about equally by amphibole on both sides. Rock may originally have contained small amounts of ol, but this is difficult to determine because of total replacement by amphibole and deformation.

## THIN SECTION DESCRIPTION

**118-735B-31R-2 (Piece 4D, 120-122 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 3 | 1.0-5.0 | | Anhedral | |
| Plagioclase | 44 | 47 | 0.5-2.0 | | Anhedral | Partially recrystallized. |
| Clinopyroxene | 25 | 50 | 5.0-12.0 | | Anhedral | Patchy replacement by pale hbd. |
| Opaque | Tr | Tr | 0.1-0.5 | | Subhedral-anhedral | At rim of cpx. |
| Orthopyroxene | Tr | Tr | 0.2 | | Anhedral | Inclusion in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 2 | Vein | With hbd. |
| Actinolite | 1 | Ol | Tremolite. |
| Hornblende | 25 | Cpx | Green, in vein with plag; also brown, replacing cpx. |
| Mica | 1 | Plag | |
| Prehnite | <1 | Plag, ol | Reaction corona between plag and ol. |
| Talc | <1 | Ol | Mixed with magnetite. |
| Magnetite | <1 | Ol | Mixed with talc. |

**COMMENTS:** Cut by two parallel green hbd veins. Cpx and hbd are recrystallized along shears through cpx.

## THIN SECTION DESCRIPTION

**118-735B-31R-3 (Piece 10, 33-35 cm)**

**ROCK NAME:** Olivine-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0 | 1 | 3.0-4.0 | | Anhedral | |
| Plagioclase | 69 | 70 | 10.0-15.0 | | Anhedral | |
| Clinopyroxene | 26 | 29 | 5.0-10.0 | | Anhedral | Subophitic to ophitic (encloses plag ophitically). |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Green amphibole | 4 | Cpx | Replaces cpx on grain boundaries, rimming tremolite after ol and along fractures. |
| Brown amphibole | <1 | | |
| Tremolite | 1 | Ol | |
| Magnetite | Tr | | |

**COMMENTS:** Slide is really too small to adequately characterize such a coarse-grained rock modally or texturally. Appears to have cumulus plag and cpx. Most replacement of cpx by amphibole occurs where veins are crosscut by amphibole-filled fractures.

## THIN SECTION DESCRIPTION

**118-735B-31R-4 (Piece 9A, 118-120 cm)**

**ROCK NAME:** Foliated amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 1 | | | | |
| Plagioclase | 10 | 59 | | | Irregular | Almost completely recrystallized. |
| Clinopyroxene | 10 | 40 | | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Brown. In cracks of plag crystals. |
| Chlorite | 1 | Amphibole | Blue interference color. Pale yellow, colorless. Associated with actinolitic hbd. Also brown interference color replaced by actinolite. |
| Actinolitic hornblende | 20 | Cpx | Green to dark green to colorless. Granoblastic. Occurs at outer margins of cpx grains, proceeding inside phenocrysts. |
| Plagioclase | 49 | Plag | Neoblasts and granoblasts. |
| Brown amphibole | 6 | Cpx | Brown. Medium brown as rims around cpx. |
| Blue-green amphibole | 3 | Amphibole | Blue-green. Idioblastic prisms. Penetrating into cpx pseudomorphs or filling space between plag and cpx crystals. Deformed into reactivated planes (foliation). |
| Talc | 1 | Ol | Very fine lamellae at outer margin of assemblages of actinolite + chlorite. Seems to replace chlorite. |
| Magnetite | Tr | Ol(?) | Associated with chlorite + tremolite ± talc. |

**COMMENTS:** Nice zonation in cracks in cpx: brown amphibole lining green amphibole center.
Single rimmed amphibole grains, same scenario.
Again assemblages of chlorite + tremolite ± talc ± magnetite could have been ol.
Initial form is highly modified (lenses to schistose).

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## THIN SECTION DESCRIPTION

**118-735B-32R-1 (Piece 1F, 64-66 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 8 | <4 | | Rounded | Allotriomorphic texture. Sometimes surrounded by opaques. |
| Clinopyroxene | 63 | 79 | <15 | | Subhedral | Large grains. Exsolution lamellae pattern replaced by amphibole along cleavages and fractures. |
| Ilmenite/magnetite | 8 | 10 | <7 | | Anhedral | Large grains outlined by colorless tremolite and minute magnetite grains. Ilmenite/magnetite intergrowths. |
| Amphibole | 3 | 3 | <0.3 | | Anhedral | Strongly pleochroic patches. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 5 | Cpx | Colorless. Replaced by actinolite close to cpx. Locally replacing cpx. |
| Hornblende | 5 | Cpx | Colorless patches replacing cpx. |
| Magnetite | Tr | Ilmenite | Very fine (<0.04 mm). Distributed around large ilmenite grains. |
| Tremolite | 9 | Cpx, plag | Colorless. Fine needle-like crystals. Associated with chlorite, blue-green amphibole, and partially replacing plag. |
| Sulfides | Tr | | Pyrite in altered zones. |
| Oxides | 2 | | Magnetite associated with alteration of cpx. |

**COMMENTS:** Cpx + plag + fluid produced blue-green amphibole + chlorite
Low grade static metamorphism.

## THIN SECTION DESCRIPTION

**118-735B-32R-3 (Piece 1B, 14-16 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 6 | 2-4 | | Anhedral | |
| Plagioclase | 64 | 64 | 1-10 | | Anhedral | |
| Clinopyroxene | 29 | 30 | 1-6 | | Anhedral | Grains mostly equant, not ophitic or subophitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | |
| Amphibole | 4 | Ol | Colorless. |
| Amphibole | Tr | Cpx | Brown. Patchy replacement in cpx and interstitial between plag crystals. |
| Amphibole | 2 | Ol, cpx | Green. Rims altered ol and in fracturus. Also replacing cpx on grain boundaries. |

## THIN SECTION DESCRIPTION

**118-735B-32R-3 (Piece 1E, 54-60 cm)**

**ROCK NAME:** Olivine-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 12 | 20 | 4-30 | | | Recrystallized, tremolite pseudomorphs after ol. |
| Plagioclase | 40 | 50 | 1-5 | | | Bent, recrystallized, crushed. |
| Clinopyroxene | 20 | 30 | 2-8 | | | Recrystallized to hbd. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Brown. In fractures cutting plag. |
| Chlorite | Tr | Plag | Pale. Replacing plag. |
| Albite | 10 | Plag | Veins in plag. In felsic veins (see below). |
| Epidote | Tr | Plag | Zoisite. In crushed zones. |
| Actinolite | 5 | Cpx, plag | Green to pale brown, in fine aggregates. |
| Hornblende | 5 | Cpx, plag, ol | Bright green in fractures in plag and recrystallized cpx. Brown, occuring with albite in veins; replacing ol + plag, cpx + plag. |
| Talc | 1 | Ol | Occurs with magnetite. |
| Tremolite | 5 | Ol | Bladed aggregates; fibrous bundles. Some could be prehnite. |
| Magnetite | 1 | Ol | In ol pseudomorphs. |

**COMMENTS:** Shear zones contain albitized fragments of plag, and small fibers of actinolite.

## THIN SECTION DESCRIPTION

**118-735B-32R-4 (Piece 1E, 43-49 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 10 | | | | Pseudomorphs of talc, tremolite and carbonate. |
| Plagioclase | 35 | 45 | | | | Cut by numerous veins. |
| Clinopyroxene | 30 | 45 | | | | Replaced by hbd and actinolite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | |
| Carbonate | 1 | Ol | |
| Chlorite | 2 | Plag | |
| Albite | 8 | Plag | Fractures in plag, also in sheared vein. |
| Actinolite | 10 | Cpx | Fibrous. |
| Hornblende | 5 | Cpx | Green, veins in plag, margins of cpx (brown symplectite with cpx). |
| Talc | 1 | Ol | With magnetite. |
| Mica | Tr | Plag, ol | Higher relief than talc. |
| Tremolite | 2 | Ol | Replacing ol. |

**COMMENTS:** Vein cutting gabbro is green hbd. Where it is sheared, it is mixed with sodic plag.

## THIN SECTION DESCRIPTION

**118-735B-33R-2 (Piece 6, 60-62 cm)**

**ROCK NAME:** Metagabbro (amphibolitized)

**WHERE SAMPLED:**

**TEXTURE:** Brecciated

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 56 | 60 | | | | Concentrically zoned. |
| Clinopyroxene | 5 | 38 | | | | |
| Ilmenite | 1 | 2 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 1 | Plag | Rims of plag and along small fractures. |
| Epidote | 3 | Plag | Anomalous blue interference color, small grains. |
| Actinolite | 8 | Cpx | Acicular, replaces cpx in aggregate patches. |
| Sphene | 1 | Ilmenite | Pinkish. |
| Hornblende | 25 | Cpx | Green-yellow or green-blue pleochroism. |

**COMMENTS:** Cpx is replaced by green amphibole and recrystallized along S-shaped microshears. Displacement of relict cpx cleavages suggests that cpx was deformed prior to (or synchronous with?) replacement by amphibole. Neoblasts of cpx in shear are not replaced by amphibole. The plag is broken and veined but not very crushed. Brecciated appearance is due to albite veining and replacement by epidote.

## THIN SECTION DESCRIPTION

**118-735B-33R-3 (Piece 7, 85-89 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Poikilitic

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.7 | 2.2 | 2.0 4.0 | | Subhedral | Minor kink banding in ol. |
| Plagioclase | 67.0 | 68.4 | 2.0-12. | | Subhedral-euhedral | Large grains aligned, minor recrystallization of plag. |
| Clinopyroxene | 24.9 | 29.3 | 2.0-10.0 | | Oikocrystic | Oikocrysts enclosing plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.4 | Plag | Commonly occurs around ol pseudomorphs where it replaces plag. Intergrown with tremolite. |
| Actinolite/Tremolite | 1.4 | Ol | |
| Hornblende | 4.5 | Cpx | Both brown and green varieties occur as rims around cpx and in veins and patches. |
| Magnetite | 0.1 | Ol | Occurs in association with tremolite around ol relicts and as ol pseudomorphs. |

**COMMENTS:** Dislocation in plag along fractures causes offsets of twin lamellae. Large plag grains give sample layered appearance with plag layers separating regions with abundant cpx oikocrysts.
Percentages based on 200 points. Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-33R-4 (Piece 2B, 27-29 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** 0.1-1.0cm

**OBSERVER:** NAT

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0 | 5 | | | | Granulated plag. |
| Plagioclase | 60 | 60 | | | | Neoblasts approximately 10%. |
| Clinopyroxene | 25 | 35 | | | | Cpx partially transformed to brown/green amphiboles; twisted cleavage. |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING | COMMENTS | COMMENTS |
|---|---|---|---|---|
| Magnetite | 1 | | | Associated with white-green amphibole (tremolite/actinolite). |
| Ilmenite | Tr | | | |
| Amphibole | 14 | | | 1% brown, 5% white, remainder green. White and green amphibole together replace ol. |

**COMMENTS:** Rock was formerly an ol gabbro, now it is moderately foliated and granulated but nowhere mylonitized.

## THIN SECTION DESCRIPTION

**118-735B-33R-4 (Piece 10, 129-131 cm)**

**ROCK NAME:** Altered olivine microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Altered cumulate

**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 15-20 | | | | Patches of talc, opaques and tremolite probably replacing ol. |
| Plagioclase | 40 | 60-60 | 0.4 | | | Partially altered to green actinolite. |
| Clinopyroxene | 0 | 5-20 | | | | No relicts, may be replaced by patches of coarse-grained green amphibole. |
| Orthopyroxene | — | ? | | | | No relicts; some of the talc and tremolite may replace it. |
| Brown hornblende | Tr | Tr | | | | Patches in green hbd. Late primary or early secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 3 | Plag | Along cracks in the plag. |
| Talc/Tremolite/Opaques | 17 | Ol(?) | Occurs as patches with actinolitic rims.[1] |
| Actinolite | 40 | Plag, cpx, veins | |

**COMMENTS:** Rock is not significantly deformed. There are however thin shears with deformed green amphibole and highly crushed plag. Thin section is cut from the end of a minicore.

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## THIN SECTION DESCRIPTION

**118-735B-34R-1 (Piece 10, 103-105 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Poikilitic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 11.7 | 20.3 | 0.5 | | Anhedral-subhedral | Oikocryst encloses plag. Some are included in cpx; subhedral, altered to tremolite and opaques. |
| Plagioclase | 47.6 | 49.3 | 1.0-8.0 | | Euhedral-subhedral | Chadacryst in cpx, rarely in ol, veined by amphibole. |
| Clinopyroxene | 25.7 | 30.0 | 10.0-20.0 | | Anhedral | Oikocrysts encloses plag. In this section only two grains are recognized |
| Spinel/Fe-Ti oxide | Tr | Tr | 0.1-0.3 | | Euhedral-subhedral | Inclusion in ol, cpx near their rims. Inclusion in plag. |
| Hornblende | 0.1 | 0.2 | 0.1-0.2 | | Anhedral | Pale brown, rimming ol and cpx. Also replacing cpx and accompanying Fe-Ti oxide. |
| Orthopyroxene | 0.2 | 0.2 | 0.1-0.2 | | Anhedral | Exsolution lamellae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.6 | Ol | Yellowish green, filling irregular cracks in ol, no pleochroism. |
| Carbonate | 0.1 | Ol | Replacing ol. |
| Chlorite | 0.3 | Plag | |
| Actinolite | 2.8 | Tremolite, cpx, hbd, vein | Replacing cpx and brown hbd. Occurs at the outer margin of tremolite corona replacing ol, veins in plag and cpx. |
| Tremolite | 3.8 | Ol | Rimming ol with Fe-Ti oxide. |
| Mica | 5.1 | Ol | Reaction corona between tremolite after ol and plag. Some replaces ol as large single grain 1.0 mm across. |
| Magnetite | 1.0 | Ol | Accompanied by tremolite replacing ol, in reaction zones. |

**COMMENTS:** No evidence of deformation except for kink bands in ol. Plag is not affected by deformation: no recrystallization, no wavy extinction. Cpx is a large (2cm) cpx oikocryst. Oikocryst ol contains many minute opaque inclusions. One half of the thin section is ol-rich; the other half is cpx-rich. Percentages based on 1500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-34R-2 (Piece 1C, 18-22 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:** Below the portion of the core showing grain size variation.

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 14 | 0.5–5.0 | | Anhedral | Replaced by tremolite + opaques. These pseudomorphs are further rimmed by chlorite and mica. |
| Plagioclase | 61.7 | 64 | 0.5–8.0 | | Subhedral–anhedral | Veined by actinolite. |
| Clinopyroxene | 21.4 | 22 | 1–8 | | Anhedral | Mostly oikocrystic. Replaced by amphibole. |
| Opaque | Tr | Tr | 0.03–0.30 | Sulfide | Subhedral–anhedral | Inclusion in cpx, plag. Rimming cpx and ol. Commonly accompanied by brown hbd. |
| Hornblende | Tr | Tr | 0.1–0.2 | | Anhedral | Pale brown, rimming cpx, ol, opaques, replacing cpx. |
| Orthopyroxene | Tr | Tr | ≈0.2 | | Anhedral | Inclusions or exsolution lamallae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.5 | Ol | Greenish brown, filling cracks in ol. |
| Chlorite | 0.9 | Ol | Reaction corona between tremolite after ol and plag. |
| Actinolite | 0.5 | Cpx, plag, hbd | Veins in plag, and replacing cpx and hbd. |
| Tremolite | 2.4 | Ol | |
| Mica(?) | 2.3 | Ol, plag | Rims around tremolite + opaques aggregate. Replacing ol rim. Reaction corona between plag and altered ol. |

**COMMENTS:** Ol has many kink bands, but plag in almost undeformed.
No prefered orientation.
Percentages based on 2000 point counts.

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## THIN SECTION DESCRIPTION

**118-735B-34R-4 (Piece 2, 8-12 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulus

**GRAIN SIZE:** Very coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.7 | 2.5 | 1.0-2.0 | | Anhedral | Relicts and pseudomorphs occur as thin films around Fe-Ti oxides. Partially encloses cpx. |
| Plagioclase | 42.3 | 42.4 | 10.0-17.0 | An 38 | Subhedral | Partially recrystallized. |
| Clinopyroxene | 32.2 | 32.9 | 5.0-15.0 | | Subhedral–anhedral | Intergrowths between large grains of cpx, occasionally with plag. |
| Fe-Ti oxide | 20.8 | 20.8 | 3.0-15.0 | | Anhedral | Sometimes encloses ol which encloses cpx. |
| Orthopyroxene | 1.2 | 1.2 | 3.0 | | Anhedral | May have been pigeonite, enclosed in Cpx; may also represent exsolution from subcalcic augite. |
| Hornblende | 0.2 | 0.2 | 0.5 | | Anhedral | Brown, occurs as blebs in cpx, often associated with Fe-Ti oxides. Also occurs in interstices between grains, most noticeably between large plag grains. |
| Sulphide | Tr | Tr | | | Anhedral | Interstitial between cpx grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.6 | Ol | Deep brownish yellow clay veining and replacing ol. |
| Chlorite | 0.1 | Plag | Pale green, pleochroic, anomalous blue interference color. Occurs interstitially between cpx and plag. |
| Actinolite/Tremolite | | Ol, plag | Occurs along grain boundaries and in veins through plag. |
| Hornblende | 0.6 | Cpx | Green and brown varieties most commonly found along margins of cpx but also as patches in plag. |

**COMMENTS:** Pyroxenes and ol exhibit reaction relationships: Ca-poor pyroxene + liquid to ol + Ca-rich pyroxene.
Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-34R-4 (Piece 4, 30-32 cm)**

**ROCK NAME:** Porphyroclastic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Variable

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 75 | 5.0-7.0 | | Anhedral | Porphyroclasts with subgrain boundaries, granoblasts and neoblasts. Open microfractures filled with green amphibole. |
| Clinopyroxene | 5 | 25 | <5.0 | | Anhedral | Almost completely replaced by green, brown and blue-green amphiboles. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | <1 | Green amphibole | Blue interference colors. |
| Hornblende | 20 | | Green pseudomorphs after cpx, recrystallized into small granoblasts in a mylonitic band. |
| Plagioclase | 36 | Plag | Granoblasts and neoblasts, less than 0.5 mm, partly chloritized. |
| Blue-green amphibole | 5 | Green amphibole | Replacing amphibole pseudomorhps, particularly in deformed area. |
| Brown amphibole | 3 | Green amphibole | In association with green amphibole in recrystallized areas lined by blue-green amphibole. |
| Ilmenite | 1 | | Anhedral grain at plag and cpx boundaries locally altering to sphene. |

**COMMENTS:** Dynamic metamorphism of medium grade, post-dating formation of brown amphibole and synformation of blue green amphibole.

## THIN SECTION DESCRIPTION

**118-735B-35R-1 (Piece 2C, 29-31 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5.7 | 11.9 | 0.5-5.0 | | Anhedral | Rounded in plag to very irregular between plag and cpx. |
| Plagioclase | 56.0 | 56.0 | 0.5-6.0 | | Euhedral to anhedral | |
| Clinopyroxene | 21.8 | 32.1 | 1.0-6.0 | | Anhedral | Oikocrysts around plag, rarely around ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 0.8 | | In cpx replacements. |
| Actinolite | 9.2 | Cpx | Approximately 2% in veins, 1% in aggregates not identifiable as cpx or ol pseudomorphs. |
| Hornblende | <0.1 | Cpx | Rare brown amphibole in cpx. |
| Spinel | 0.1 | Ol | Small grains in ol pseudomorphs. |
| Talc/Tremolite | 6.2 | Ol | Mixed granular/fibrous aggregates. |

**COMMENTS:** Very fresh; plag are all quite undulose, some with thin spindle-shaped twins indicating slight deformation.

## THIN SECTION DESCRIPTION

**118-735B-35R-1 (Piece 2E, 45-47 cm)**

**ROCK NAME:** Olivine gabbro with pyroxenite layer

**WHERE SAMPLED:** Contact between olivine gabbro and pyroxenite layer

**TEXTURE:** Anhedral to equigranular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 17 | 0.5-3.0 | | Euhedral–subhedral | Unaltered grains have many kink bands. Alteration into tremolite and opaque, talc, actinolite and chlorite, brown clay. |
| Plagioclase | 50 | 55 | 0.5-4.0 | | Subhedral–anhedral | Wavy extinction common, veined bt albite, amphibole and chlorite. |
| Clinopyroxene | 22 | 26 | 1.0-5.0 | | Anhedral | Partly rimmed by brown amphibole, the margin is slightly replaced by amphibole. |
| Fe-Ti oxide | 1 | 1 | 0.1-0.5 | | Subhedral | As inclusion in cpx, at the rim of cpx accompanied by brown hbd. |
| Brown hornblende | 1 | 1 | 0.3-0.6 | | Anhedral | Rimming cpx, replaced by greenish hbd and actinolite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Ol | Replacing ol at the latest stage of alteration. Brown to greenish-brown. |
| Chlorite | 4 | Ol, vein | Replacing ol and occurs as vein in plag. |
| Albite | 2 | Plag | As vein in plag. |
| Actinolite | 4 | Cpx, hbd | Replacing cpx and brown hbd. |
| Green hornblende | 3 | Cpx, vein | Veining plag, rimming cpx. |
| Tremolite | 3 | Ol | Replacing core of ol. |
| Talc | 3 | Ol | Replacing margin of ol. |
| Fe-Ti oxide | 1 | Ol | Accompanying tremolite and replaces ol. |

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| PYROXENITE LAYER | | | | | | |
| Clinopyroxene | 52 | 56 | 2.0-10.0 | | Anhedral | Opx and pigeonite exsolution bleb, partly replaced by brown hbd. Also replaced by actinolite. |
| Inverted pigeonite | 25 | 35 | 6.0-12.0 | | Anhedral | Opx host is partially replaced by tremolite, but exsolved cpx is well preserved. |
| Olivine | 0 | 2 | 1.0-2.0 | | Euhedral | Inclusion in cpx, altered into greenish to yellowish-brown clay. |
| Orthopyroxene | 1 | 1 | 0.5-1.0 | | Anhedral | Primary? Rimming ol in cpx. |
| Plagioclase | 5 | 5 | 0.4-5.0 | | Anhedral | Filling interstitial space. |
| Fe-Ti oxide | 2 | 3 | 0.2-2.0 | | Anhedral–euhedral | Small grains as inclusion in pyroxene. Cracked and filled by carbonate. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Replacing ol at the latest stage of alteration. Brownish to greenish-brown. |
| Carbonate | 1 | Fe-Ti oxide vein | Filling cracks in opaque. |
| Actinolite | 5 | Cpx, hbd | Replacing cpx and brown hbd. |
| Tremolite | 10 | Ol | Replacing core of ol. |

**COMMENTS:** Ol is commonly rimmed by cpx in gabbro.

## THIN SECTION DESCRIPTION

## 118-735B-35R-2 (Piece 4G, 105-108 cm)

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate to granular

**GRAIN SIZE:** Coarse to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 53 | 70 | 1.0-4.0 | | Subhedral—anhedral | Undulose, partly deformed. |
| Clinopyroxene | 10 | 30 | ≤ 2.0 | | Anhedral | Large oikocrysts in some cases, now largely amphibolitized. |
| Orthopyroxene | 1 | 2 | 2.0-3.0 | | Euhedral | Altered, deformation twins; identification uncertain. |
| Oxides | Tr | | | | | Ilmenite/magnetite, intercumulus(?) |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | On fractures through plag. |
| Epidote | 2 | Plag? | High relief, moderate birefringence near deformed zones, 0.1-0.2 mm grains. |
| Actinolite | 20 | Cpx | Pale green masses and crystal aggregates after cpx, also in veins. |
| Hornblende | 1 | Cpx | Brown amph in altered cpx patches. |
| Plagioclase | 10 | Plag | Neoblasts on grain margins. |
| Magnetite | 1 | Cpx | Anhedral, associated with actinolitic patches; magnetite reaction zone. |
| Sulphide | Tr | | Pyrite, possibly primary. |
| Phlogopite | Tr | Plag | On margins with opx. |

**COMMENTS:** Sample is cut by 1cm wide deformation zone with large rounded porphyroclasts surrounded by fine, granulated plag (description is for sample outside deformation zone), 0.5-1.5 mm subrounded clots of greenish-brown mineral. Fine-grained aggregates, clay-like, appear milky green-white in thin section. By eye, deformation is localized but has effected entire rock to some degree. Minerals in deformed zone include sodic plag, quartz, actinolite, and diopside.

## THIN SECTION DESCRIPTION

## 118-735B-35R-4 (Piece 2A, 43-46 cm)

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8.6 | 16 | 0.5–4.0 | | Anhedral | Granular aggregates, measuring up to 6 mm. |
| Plagioclase | 49.0 | 50 | 0.2–6.0 | | Euhedral-anhedral | Undulose extinction. Some granulation, recrystallization. |
| Clinopyroxene | 24.8 | 34 | 2–8 | | Anhedral | Ophitic to poikilitic. |
| Opaque | Tr | Tr | | | | Probably a sulphide. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Plag | Filling cracks in plag. |
| Chlorite | 0.5 | Ol, cpx | Occurs with actinolite + tremolite on the outside rim of pseudomorphs. |
| Albite | 0.4 | Plag | Occurs along a fracture on one side of the slide. |
| Epidote | Tr | Plag | Occurs along a fracture on one side of the slide. |
| Actinolite | 9.0 | Cpx, veins | 7% replacing cpx, 2% in veins. |
| Talc/tremolite | 6.7 | Ol | |
| Opaques | 0.7 | Ol | In pseudomorphs. |

## THIN SECTION DESCRIPTION

**118-735B-35R-5 (Piece 5E, 131-135 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 0.5–2.0 | | Anhedral | Irregular. Partially altered to opaques, talc. |
| Plagioclase | 50 | 54 | 0.5–4.0 | | Anhedral | Slightly undulose extinction. |
| Clinopyroxene | 30 | 36 | 1–4 | | Anhedral | Partially enclosing some plag crystals, and rare ol crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Plag | Dusty brown crystals along fractures in plag and cleavage planes in cpx. |
| Actinolite | 7 | Cpx, vein | Actinolitic hornblende, green to pale green. |
| Talc | 2 | Ol | |
| Opaques | Tr | Ol | After ol. Also 0.05 mm anhedral grains in groundmass. |

**COMMENTS:** Relatively fresh ol gabbro with minor oxides.

## THIN SECTION DESCRIPTION

**118-735B-35R-7 (Piece 2, 14-17 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN/STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 13 | 10–20 | | Anhedral | Not very well marked meta-grain boundaries. |
| Plagioclase | 75 | 85 | | | Anhedral | Locally crushed and recrystallized. |
| Clinopyroxene | 2 | 2 | 10 | | Subhedral | Occasional kinked crystals. |
| Orthopyroxene | <1 | <1 | 1 | | Subhedral | Small crystals along the edges of ol. |
| Hornblende | <1 | <1 | | | | Brown. Primary or early secondary phase. |
| Opaque | <<1 | <<1 | | | | Primary or early secondary phase. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 4 | Ol | Center of ol is altered to clay + disseminated opaques. |
| Chlorite | 1 | Plag | Occurs in rims of plag along ol replacement zones. |
| Plagioclase | <10 | Plag | Recrystallized grains in crushed zones. |
| Actinolite | 1 | Ol, cpx, plag | |
| Hornblende | Tr | Cpx, hbd | Green. Also filling cross-cutting veinlets. |
| Tremolite | <1 | Ol | Occurs with actinolite in ol rims. |
| Talc | <1 | Ol | Occurs with actinolite in ol rims. |
| Mica | <1 | Ol | Occurs with actinolite in ol rims, phlogopite. |
| Opaques | 2 | Ol | Disseminated opaque occuring with clay. |

**COMMENTS:** In the ol replacement zones, two phylosilicates are locally present (excluding talc). One is brown, very pleochroic, phlogopite. The other is colorless, high relief and low birefringence, possibly clintonite. The crushing and recrystallization of plag appears to predate the hydrous replacement described. Very green hbd in veins shows sector zoning, characteristic of growing into a void. Ol is extensively oxidixed.

## THIN SECTION DESCRIPTION

**118-735B-36R-1 (Piece 3, 17-20 cm)**

**ROCK NAME:** Altered olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to very coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 15 | 21 | 0.1-3.0 | | Anhedral | Fragments of original grains which measured up to 1.5 cm. |
| Plagioclase | 25 | 30 | 0.1-12 | | Anhedral | Broken grains with sutured boundaries. |
| Clinopyroxene | 8 | 49 | 0.1-4.0 | | Anhedral | Shreds of original cpx in some pseudomorphs. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | Ol, cpx | In dark, hematite-stained clots at cores of some ol pseudomorphs. |
| Clays | Tr | Voids | Green. Filling void spaces. |
| Fe-Mg amphibole | 16 | Cpx, ol | Pale green to colorless aggregates after cpx, ol. Also in some veins or fractures (probably anthophyllite). |
| Plagioclase | 5 | Plag | 0.1-0.2 mm neoblasts or granules with sutured boundaries. |
| Oxides | 4 | Ol | Granular aggregates around ol pseudomorphs. |
| Hematite(?) | 1 | Ol | |
| Amphibole | 18 | Cpx | Brown to green, well crystallized crystals. Some in veins. |
| Talc | 1 | Ol | Colorless, occuring with magnetite. |
| Diopside | 2 | Cpx | Pale inclusions in hbd. |

**COMMENTS:** Extensive deformation. Plag neoblasts, undulose-deformation twins in plag. No well developed foliation.

## THIN SECTION DESCRIPTION

**118-735B-36R-2 (Piece 1A, 11-13 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 7 | 10 | | Anhedral | Altered to talc, oxides and tremolite. Faint deformation kinks. |
| Plagioclase | 78 | 84 | >20 | | Anhedral | Some albitization. Also some alteration to actinolite. |
| Clinopyroxene | 6 | 9 | 10 | | Anhedral | Partially altered to brownish green amphibole |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 3 | Plag | Zones in the big plag porphyroclast. |
| Tremolite/ actinolite | 3 | Plag, ol | Around ol and in sealed fractures in plag. |
| Hornblende | 3 | Cpx | In and around cpx crystals. |
| Talc | 3 | Ol | Replacing ol. |

**COMMENTS:** Note: oriented thin section from the end of a minicore.
Due to large grain size and to the small thin section size, the modal proportion given here are far from representative.

## THIN SECTION DESCRIPTION

**118-735B-36R-2 (Piece 1E, 98-102 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:**
**GRAIN SIZE:** Medium
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9 | 14 | 0.4–6.0 | | Anhedral | Replacement aureole of talc + tremolite. |
| Plagioclase | 66 | 75 | 0.4–10.0 | | Anhedral–subhedral | Microfractures sealed with albite. |
| Clinopyroxene | 8 | 10 | 0.5–10.0 | | | Oikocrysts. Slight replacement by green-brown amphibole. Kinked, veinned crystals. |
| Amphibole | ≈1 | ≈1 | 50.4 | | | Forms thin aureole around cpx, ol, and opaques. Interstitial |
| Opaques | <1 | <1 | 50.4 | | Euhedral–anhedral | Surrounded by brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 9 | Plag | Occurs in microfractures, linked with veining of sample. |
| Tremolite | ≈2 | Ol | Associated with talc in replacement aureole. |
| Hornblende | 2 | Cpx, veins | Green to greenish brown. Replaced the edges of cpx, and fills thin veins which dip 90° into the plane of the thin section. |
| Talc | 3 | Ol | Associated with tremolite. |

**COMMENTS:** The ol and plag have kink bands and deformation sub-grain boundaries, but show no prefered fabric. This slight deformation is prior to the injection of the amphibole veins and the hydration of the sample.
This hydration event was accompanied with very slight cataclastic shearing of the sample.

## THIN SECTION DESCRIPTION

**118-735B-36R-3 (Piece 1B, 28-34 cm)**

**ROCK NAME:** Olivine gabbro gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular
**GRAIN SIZE:** Medium to very coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| COARSE-GRAINED LAYER | | | | | | |
| Plagioclase | 52 | 52 | 1–2 | | Subhedral | Subophitic to ophitic. Contains inclusions of ilmenite or magnetite. |
| Clinopyroxene | 41 | 48 | 0.5–1.5 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| COARSE-GRAINED LAYER | | | |
| Amphibole | 2 | Cpx | Brown. Patchy. |
| Amphibole | 5 | Cpx | Green. |

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| MEDIUM-GRAINED LAYER | | | | | |
| Olivine | 1 | 5 | 1.0–1.5 | | Anhedral |
| Plagioclase | 59 | 59 | 1–3 | | Anhedral |
| Clinopyroxene | 25 | 36 | 1.0–2.5 | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| MEDIUM-GRAINED LAYER | | | |
| Clays | <1 | Ol | |
| Magnetite | 3 | Ol | |
| Amphibole | 3 | Cpx | Brown. Patchy. |
| Amphibole | 8 | Cpx | Green. |
| Amphibole | <1 | Ol | Colorless. |

**COMMENTS:** This slide contains evidence for primary layering in grain size and modal proportions. The medium-grained layers are less cpx-rich and more ol-rich than the coarse-grained layers. Some recrystallization of plag into neoblasts in medium-grained layers.
Some recrystallization of plag into neoblasts in medium-grained layers.

## THIN SECTION DESCRIPTION

**118-735B-36R-3 (Piece 1C, 36-38 cm)**

**ROCK NAME:** Olivine microgabbro
**WHERE SAMPLED:**
**TEXTURE:**
**GRAIN SIZE:** Fine
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | <7 | 0.1–0.8 | | Anhedral | Altered to tremolite + talc + opaques. Slightly kinked. |
| Plagioclase | 60 | 65 | 0.4–4.0 | | Anhedral | Slightly crushed, recrystallized and albitized. |
| Clinopyroxene | 20 | 25 | 0.1–2.0 | | Anhedral | Altered into green amphibole near veins. |
| Orthopyroxene(?) | Tr | Tr | | | | |
| Amphibole | — | 3 | 0.2 | | | Brown interstitial crystals. Associated with cpx. Uncertain if primary or secondary. |
| Opaques | >1 | >1 | | | | Uncertain if primary or secondary. Associated with cpx and brown hornblende. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 5(?) | Plag | Bands along the green amphibole veins. |
| Tremolite | <1 | Ol | Replacement aureole. |
| Hornblende | 8 | Cpx, amphibole | Possibly actinolitic amphibole. Also in network of veins, dipping 90° into the plane of the thin section. |
| Talc | 1 | Ol | |
| Opaques | 1 | Ol | |

**COMMENTS:** A slight plastic deformation enhances the mineral shape fabric (magmatic lamination), parallel to the grain size layering observed in the sample. The deformation is empressed by small shears underlined by crushed and recrystallized plag, and by the distribution of opaques in the ol-cpx zones.

A monomineralic, 3 mm wide plag band cuts across the middle of the thin section, parallel to shears and layering in the sample.

## THIN SECTION DESCRIPTION

**118-735B-37R-1 (Piece 2A, 11-15 cm)**

**ROCK NAME:** Olivine-bearing gabbro
**WHERE SAMPLED:**
**TEXTURE:** Granular
**GRAIN SIZE:** Fine to medium
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.9 | 2 | 0.2–1.5 | | Anhedral | Occurs on one side of the slide only. |
| Plagioclase | 44.0 | 71 | 0.02–0.20 | | Anhedral | Undulose extinction. Elongate grains. |
| Clinopyroxene | 23.4 | 27 | 0.2–1.5 | | Anhedral | Some granulation and recrystallization. A few crystals partially enclose plag crystals. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol, cpx | Small dark brown/green crystals filling oval clots. |
| Chlorite | 0.8 | Cpx | Patches in cpx replacement. |
| Actinolite | 18.2 | Veins, plag | 5% occuring in veins which cut plag and grain boundaries. |
| Hornblende | 1.7 | Cpx | Brown amphibole. Patches in cpx and rimming oxides. |
| Plagioclase | 10.0 | Plag | 0.4 mm and smaller neoblasts. |
| Oxides | 0.7 | Cpx, ol | 0.2 mm primarily around cpx. 0.5 mm crystals in ol pseudomorphs. |
| Tremolite(?) | 0.2 | Ol | |

**COMMENTS:** Some deformation: bent undulose plag with some granulation and recrystallization. Cpx is also partially recrystallized, and larger grains have bent twins. The deformation is somewhat localized, as is subsequent amphibolitization. Amphibolitization is concentrated along late fractures. There is a weak lamination of cpx + plag which is possibly partially igneous.

best copy available

## THIN SECTION DESCRIPTION

**118-735B-37R-2 (Piece 1H, 113-117 cm)**

**ROCK NAME:** Metagabbro (hydrothermally altered)

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic, partially recrystallized

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2 | | | | |
| Plagioclase | 43 | 63 | 3-8 | | | Discrete recrystallized bands. Highly fractured. |
| Clinopyroxene | 6 | 30 | | | | Flattened in one pert of the slide. |
| Apatite | <1 | <1 | 5 | | | One grain, W:L = 2:5. |
| Ilmenite | 2 | 5 | | | | Replaced by sphene. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Plag | Coronas with tremolite/actinolite and blue hornblende. |
| Chlorite | 2 | Plag | Along microfractures in plag. |
| Albite | 5 | Plag | Very blue birefringence. Some euhedral crystals. Also in fractures. |
| Epidote | 10 | Plag | Corona with chlorite. |
| Actinolite | 3 | Cpx, Plag | Pale yellow, euhedral crystals. |
| Sphene | 3 | Ilmenite | Green to blue-green pleochroic, prismatic crystals associated with epidote at margins of cpx pseudomorphs. |
| Hornblende | 19 | Cpx | |
| Plagioclase | 3 | Plag | Neoblasts. |
| Talc | 1 | Ol | Occurs with magnetite in pseudomorphs. |
| Magnetite | <1 | Ol | Occurs in pseudomorphs with talc. |
| Anthophyllite | 2 | Ol | Pseudomorphs with talc. |
| Analcite | Tr | Plag | Intergrown with sphene. |

**COMMENTS:** Fractures in plag are filled with a yellowish mineral in fine-grained aggregates. Associated with epidote. Probably it is an amphibole. Some ere cracks also have the bright green hornblende. Plag-hornblende sympiectite. Could have two epidotes. Window-pane texture of chlorite and magnetite rods. epidotes.

## THIN SECTION DESCRIPTION

**118-735B-37R-3 (Piece 4, 80-82 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:** At level of fine-grained microgabbro

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2(?) | 1-2 | | Euhedral-anhedral | Replaced by dirty brownish clay + opaque. Euhedral inclusions in cpx. |
| Plagioclase | 57 | 59 | 0.3-4.0 | | Anhedral | Partially granulated, wavy extinction apparent. Veined by chlorite and amphibole. |
| Clinopyroxene | 20 | 25 | 0.5-8.0 | | Anhedral | (100) exsolution lamellae abundant. Rare (001) exsolution lamellae. |
| Oxide | 4 | 4 | 0.1-1.5 | Fe-Ti | Anhedral | Interstitial to opx. Also as inclusions in cpx. |
| Orthopyroxene | 5 | 6 | 1-4 | Pigeonite | Anhedral | Inverted pigeonite. Opx host is commonly altered into tremolite/actinolite + Fe-Ti oxide. (001) lamellae are 0.02 0.02 mm thick, irregular blebs. |
| Orthopyroxene | 1 | 2 | 0.5-1.0 | | Anhedral | In cpx as exsolution bleb(?) or primary crystals. Also occuring in an isolated grain. |
| Hornblende | 1 | 2 | 0.1-0.2 | | Anhedral | Brown. Altered into green amphibole (actinolite). Occuring at the rims of or as inclusions in cpx + Fe-Ti oxides. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol(?) | Brown to green. Replacing ol with Fe-Ti oxide. |
| Chlorite | 2 | Plag | Veins in plag and along grain boundaries of plag. |
| Actinolite | 3 | Cpx, vein, hornblende | Replacing cpx and brown hornblende from their margins. Also occuring in vein in plag. |
| Tremolite | 4 | Opx, cpx | Replacing opx (pigeonite host), accompanied by Fe-Ti oxide, tremolite. Aggregate is further veinned by actinolite. |
| Oxides | 1 | Ol, opx, cpx | Fe-Ti oxides. Anhedral grains of various size. |

**COMMENTS:** Cpx shape and mode of arrangement shows weak foliation.

## THIN SECTION DESCRIPTION

**118-735B-37R-3 (Piece 6, 95-101 cm)**

**ROCK NAME:** Ilmenite olivine microgabbro

**WHERE SAMPLED:** Contacts between ilmenite olivine microgabbro, ilmenite gabbro, and undeformed olivine gabbro (see following two descriptions)

**TEXTURE:** Allotriomorphic granular

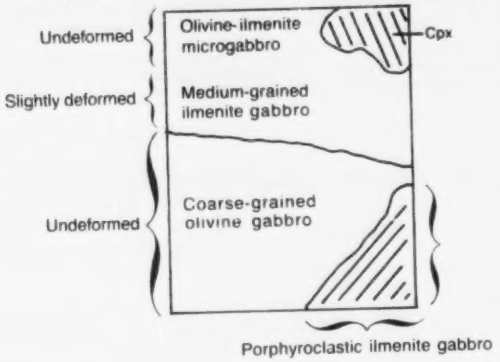
**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 11 | 17 | 0.1–0.5 | | Anhedral |
| Plagioclase | 59 | 59 | 0.2–1.0 | | Anhedral |
| Clinopyroxene | 16 | 22 | 0.2–0.6 | | Anhedral |
| Oxides | — | 2 | | Fe-Ti | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Amphibole | 2 | Oxides | Brown. Surrounds primary Fe-Ti oxides. |
| Amphibole | 6 | Amphibole, cpx, veins | Green. Replaces brown amphibole and some cpx. Also occurs along fractures. |
| Magnetite | 4 | Ol | |
| Talc-tremolite | 2 | Ol | |
| Fe oxyhydroxides | Tr | Ol | |

**COMMENTS:** This is a structurally complex sample including portions of microgabbro, ol gabbro, and porphyroclastic gabbro (see sketch). Upper right corner of microgabbro contains a single large cpx grain, ≈ 13 mm long. The microgabbro is undeformed.


Undeformed
Olivine-ilmenite microgabbro
Cpx
Slightly deformed
Medium-grained ilmenite gabbro
Undeformed
Coarse-grained olivine gabbro
Porphyroclastic ilmenite gabbro

## THIN SECTION DESCRIPTION

**118-735B-37R-3 (Piece 6, 95-101 cm)**

**ROCK NAME:** Porphyroclastic ilmenite gabbro

**WHERE SAMPLED:** See previous and following forms

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | 2-3 | 1 | | Anhedral | |
| Plagioclase | 25 | 45 | 1-3 | | Anhedral | |
| Clinopyroxene | 34 | 42 | 1-3 | | Anhedral | Locally has a rounded shape, else where more stretched and elongated. The round shape occurs where there is more ilmenite. |
| Opaques | 10 | 10 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol | |
| Plagioclase | 20 | Plag | Neoblasts. |
| Amphibole | 3 | Cpx | Brown. Patchy replacement of cpx and in pressure shadows of porphyroclasts. |
| Amphibole | 3 | Cpx | Green. |
| Magnetite | <1 | Ol | Includes some Fe-oxyhydroxides and hematite. |
| Clinopyroxene | 2 | Cpx | Neoblasts. |
| Talc-tremolite | 1 | Ol | |

**COMMENTS:** A zone of deformed ilmenite gabbro (sub-horizontal layer) separates the microgabbro described in the previous form from the ol gabbro described in the following form. It also forms one subvertical boundary of the gabbro. In one portion of the subhorizontal layer between gabbro and microgabbro, the mineralogy is very cpx-rich, almost a clinopyroxenite.

## THIN SECTION DESCRIPTION

**118-735B-37R-3 (Piece 6, 95-101 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:** Contacts between ilmenite olivine microgabbro, ilmenite gabbro, and undeformed olivine gabbro (see previous two descriptions).

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 15 | 20 | 1.0-6.0 | | Anhedral | |
| Plagioclase | 59 | 60 | 3.0-14.0 | | Subhedral | |
| Clinopyroxene | 14 | 20 | 2.0-12.0 | | Anhedral | Ophitically to subophitically enclosing plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Along with some Fe-oxyhydroxides. |
| Actinolite/Tremolite | 3 | Ol | |
| Brown amphibole | 2 | Cpx | Patchy replacement and some concentration on grain boundaries; occurs surrounding primary ilmenite and rarely in veins. |
| Actinolite | 6 | | Replaces brown amphibole, cpx and in thin veins cross-cutting plag. |
| Magnetite | 1 | Ol | |

**COMMENTS:** Relatively undeformed. A few plag crystals are fractured where crosscut by an amphibole vein. Cumulus plag, cpx and ol.

## THIN SECTION DESCRIPTION

**118-735B-38R-2 (Piece 1B, 15-17 cm)**

**ROCK NAME:** Metamorphosed microgabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | <1 | <5 | 0.4 | | Anhedral | Replaced by opaques and tremolite. |
| Plagioclase | 55 | 55 | 0.5-1.0 | | Euhedral-subhedral | |
| Clinopyroxene | 10 | 35 | 0.5 | | Subhedral | Replaced by green amphibole (actinolite?). |
| Opaques | 2 | ? | <0.4 | | Subhedral | Scattered, associated with brown amphibole. |
| Brown hornblende | Tr | ? | <0.4 | | Anhedral | Rims around opaques. |
| Sulphides | <0.5 | | | | Rounded | Much primary ilmenite. Poikilitically encloses silicates, makes embayments into silicates. Rare primary magnetite associated with primary sulphides (pyrite, pyrrhotite, etc.). |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | <1 | Vein | The carbonate coated vein looks like an open crack, dips at 45° in the section and crosscuts all the green amphibole veins. |
| Actinolite/Tremolite | 30 | Cpx, ol, veins | Regular network dipping at 70° in the plane of the section and spaced by less than 1.0 mm. |
| Magnetite | Tr | | In alteration reaction zones. |
| Pyrite | | | In alteration zones. |

**COMMENTS:** No plastic deformation. The amphibolitization is static and related to the very regular network of fine, green amphibole veins; these are extensional veins.
Oriented thin section, cut from the end of a minicore. Section is perpendicular to the fine amphibole veins.

## THIN SECTION DESCRIPTION

**118-735B-38R-2 (Piece 1B, 15-17 cm)**

**ROCK NAME:** Olivine metamicrogabbro

**WHERE SAMPLED:** Fine-grained part in contact with coarser gabbro

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Fine

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 20 | 0.1-0.5 | | Anhedral | Altered into tremolite, chlorite, Fe-Ti oxide and talc(?). Locally preserved. |
| Plagioclase | 40 | 44 | 0.1-2.0 | | Subhedral-euhedral | Some show concentric zoning. Generally, zoning pattern vague. |
| Clinopyroxene | 15 | 30 | 0.1-0.5 | | Anhedral | Altered into pale green to bluish-green amphibole, commonly rimmed by brown hbd. |
| Spinel/Fe-Ti oxide | 3 | 3 | 0.05-0.4 | | Anhedral | Often rimmed by brown hbd. |
| Brown hornblende | 2 | 3 | 0.1-0.4 | | Anhedral | Rimming cpx or opaque mineral. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 1 | Plag | Replacing plagioclase. |
| Actinolite/Green hornblende | 28 | Vein | Filling cracks cutting magmatic foliation near vertically. Replacing cpx, brown amphibole and tremolite |
| Tremolite | 5 | Ol | Replacing core of ol, 0.1-0.2 mm long, gradationally changes into actinolite at the margin. |
| Mica | 3 | Ol | Rimming ol pseudomorph; rich in slightly altered part. Talc? |
| Fe-Ti oxide | 1 | | Along cracks and margins of ol and cpx. |

**COMMENTS:** Remarkable streaks seen in thin section are amphibole veins which extensively replace cpx into amphibole. The vein is nearly vertical to the magmatic foliation indicated by plag laths.

## THIN SECTION DESCRIPTION

**118-735B-38R-2 (Piece 4B, 78-84 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Layered mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 22.6 | | 1.0-15.0 | | Anhedral-subhedral | Kink banding, some recrystallization. |
| Plagioclase | 30.8 | | 1.0-6.0 | | Anhedral-subhedral | Large plag grains recrystallized to smaller grains. |
| Clinopyroxene | 37.2 | | 1.0-15.0 | | Anhedral, poikilitic | Poikilitically encloses both ol and plag. Recrystallization at grain boundaries, particularly between large cpx grains. |
| Opaque | 0.2 | | | | | Blebs in cpx and in interstitial areas and possibly primary opaques associated with ol. |
| Orthopyroxene | Tr | | <1.0 | | | Rimming ol and occasionally cpx. A late stage magmatic product. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.0 | Plag | Rims around ol pseudomorphs that are enclosed in plag. |
| Actinolite/Tremolite | 3.3 | Ol | Rims around and pseudomorphs after ol. |
| Hornblende | 2.3 | Cpx | Rims around cpx. |
| Magnetite | 1.0 | Ol | Occurs with tremolite pseudomorphing ol. |
| Micaceous mineral | 1.6 | Plag | Looks like talc in thin section but clearly replaces plag. Occurs at outer rim in reaction coronas around ol relicts and pseudomorphs. |

**COMMENTS:** Ol, plag and cpx are all partly recrystallized but the outlines of the primary grains are still evident. Layering is manifested by bands rich in ol and cpx separated by plag-rich band. Grains also exhibit subparallel alignment, parallel to layering. Layering dips at approximately 50° in vertically oriented thin section.

## THIN SECTION DESCRIPTION

118-735B-39R-1 (Piece 1E, 60-68 cm)

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 17 | 2.0-11.0 | | Anhedral | |
| Plagioclase | 61 | 65 | 5.0-20.0 | | Anhedral | Some granulation at grain boundaries |
| Clinopyroxene | 14 | 18 | 4.0-12.0 | | Anhedral | |
| Opaques | | Tr | | | | |
| Orthopyroxene | | Tr | | | | Exsolution lamellae and patches in cpx |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Occurs with Fe-oxyhydroxides and hematite after ol, often with an outer rim of talc/tremolite and magnetite. |
| Plagioclase | 4 | Plag | Neoblasts. |
| Brown amphibole | <1 | Cpx | Surrounds primary Fe-Ti oxides, patchy replacement in cpx. |
| Green amphibole | 4 | Cpx | Some blue-green; replaces along grain boundaries and in fractures across plag. |
| Talc/Tremolite | 3 | Ol | |
| Magnetite | 1 | Ol | |
| Fe-oxides | 2 | Ol | Orange-brown Fe-oxyhydroxides and hematite. |

## THIN SECTION DESCRIPTION

118-735B-39R-1 (Piece 3, 145-147 cm)

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** DLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 11 | 15 | 0.1-2.0 | | Anhedral | Granular, elongate aggregates up to 6.0 mm |
| Plagioclase | 54 | 70 | 0.1-4.0 | | Anhedral | Undulose, sutured porphyroclasts |
| Clinopyroxene | 11 | 15 | 0.5-4.0 | | Anhedral | Enclosing euhedral plag in places, elongate, undulose |
| Oxide | 0.5 | | 0.1 | | Anhedral | Associated with cpx |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Plag | Thin dusting along fractures in plag |
| Actinolite | 3 | Cpx | Replacing cpx. |
| Hornblende | 1 | Cpx | Brown amphibole, blebs in cpx, rimming primary oxide |
| Plagioclase | 15 | Plag | Sutured neoblasts <0.1mm. |
| Oxide | 0.5 | | Exsolution? in cpx. |
| Clinopyroxene | 2 | Cpx | Neoblasts |
| Talc | 1 | | |

**COMMENTS:** Weak foliation defined by elongation of cpx and plag (moderate deformation); may have been an original layering. Ol is concentrated at opposite ends of slide and cpx across the middle.

## THIN SECTION DESCRIPTION

**118-735B-39R-3 (Piece 1C, 21-23 cm)**

**ROCK NAME:** Metamorphosed olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 0-5 | 2.0 | | | No relicts, but could be replaced by some tremolite + opaque + calcite zones. |
| Plagioclase | 60 | 60 | 2.0 | | | Albitized and fractured, deformation twins. |
| Clinopyroxene | 8 | 30 | 2.0 | | | Occasional kink in relict, replaced by green amphibole linked to veins. |
| Orthopyroxene? | Tr | 0-7 | 1.0 | | | One remnant in aureole of opaques and tremolite. |
| Brown hornblende | Tr | Tr | 0.1 | | | Interstitial, close to cpx. Possibly secondary |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Cpx, ol, plag | Unstrained. |
| Carbonate | < 1 | Ol or cpx | Replacement of mafic mineral. |
| Albite | 5 | Ca-plag | Fills sealed microfractures. |
| Actinolite/Tremolite | 3 | Ol or cpx | Replacement of mafic mineral. |
| Green hornblende | 20 | Cpx, veins | Crosscutting foliation with 75° dip in face of thin section. |
| Opaques | 1 | Ol or opx | Magnetite replacing mafic minerals, hematite from oxidation of magnetite. |

**COMMENTS:** The amphibolitization is accompanied by fractures and crushing of the plag, ie. cataclastic deformation. It is not clear what amount of plastic deformation the sample underwent before this hydration event. The well-defined foliation could be partly a magmatic inheritance.
Thin section is from the end of a minicore, and is oriented perpendicular to foliation.

## THIN SECTION DESCRIPTION

**118-735B-40R-2 (Piece 1H, 62-64 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic, poorly foliated

**GRAIN SIZE:** medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | (?) | (?) | | | Possibly opx. Tremolite-talc pseudomorphs. |
| Plagioclase | 40 | 60 | 2-4 | | | Porphyroclasts. |
| Clinopyroxene | 18 | 37 | 3-5 | | | Porphyroclasts. |
| Magnetite | 1 | 2(?) | | | | |
| Hornblende | 1 | 1 | | | | Interstitial. Jackets ilmenite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Cpx(?) | Dark with blue interference colors. Late, interstitial. |
| Albite | Tr | Plag | Along crack and grain margins. |
| Epidote | 1 | Cpx | Blue interference colors. Late. |
| Actinolite | 6 | Plag, cpx | Small needles in plag. Also green fringe on cpx; postdeformational. |
| Hornblende | 5 | Cpx | Green-brown. Syndeformational. |
| Plagioclase | 20 | Plag | Neoblasts. Syndeformational. |
| Clinopyroxene | 3 | Cpx | Neoblasts. Syndeformational. |
| Tremolite | 3 | Ol, opx | Colorless, bladed mineral mixed with talc + magnetite. Postdeformational. |
| Ilmenite/magnetite | 1 | Ilmenite(?) | Patchy. Possibly primary. Sphene around some ilmenite. |

**COMMENTS:** Mineral elongation of cpx. Some trails of hbd + cpx neoblasts at sides of augen in developing foliation. Alteration of plag along grain-grain boundaries appears to be a fine-grained mixture of epidote(?) + fibrous amphibole. Plag is also cut by thin lines of albitized zones.

## THIN SECTION DESCRIPTION

**118-735B-40R-4 (Piece 1A, 1-5 cm)**

**ROCK NAME:** Olivine microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Foliated

**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 12 | 0.4–3.0 | | Anhedral | Altered to talc + tremolite + opaque. Kinked crystals. |
| Plagioclase | 61 | 61 | 1–3 | | Anhedral | Fresh. Kinked crystals and good prefered orientation. |
| Clinopyroxene | 18 | 21 | 0.4–3.0 | | Anhedral | Replaced by green amphibole near veins. |
| Orthopyroxene | 3 | 3 | 0.4–1.0 | | Anhedral | Between the ol and cpx grains (reaction product?). |
| Hornblende | 1 | 1 | 0.2 | | | Brown. Interstitial around cpx. |
| Opaques | 2 | 2 | 0.1–0.4 | | Euhedral–anhedral | Associated with hbd around cpx. Also replacing ol. Difficult to distinguish. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite actinolite | 2 | Ol, opx(?) | In zones close to amphibole veins which dip ≈80° into the plane of the thin section (crosscutting the foliation). |
| Hornblende | 3 | Cpx, veins | Blue-green in veins. |
| Talc | 2 | Ol | In zone close to amphibole veins. |

**COMMENTS:** The plastic deformation is slight. However, sub-grain boundaries and probably a rough fabric in ol, and a good fabric in plag (possibly formed partially magmatically) were produced.

## THIN SECTION DESCRIPTION

**118-735B-40R-5 (Piece 2, 13-15 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 6 | 0.1–1.0 | | Anhedral | |
| Plagioclase | 58 | 58 | 0.5–2.5 | | Anhedral | |
| Clinopyroxene | 35 | 35 | 0.1–2.0 | | Anhedral | Partially enclosing ol and often totally enclosing ilmenite. |
| Ilmenite | 1 | 1 | 0.05–0.25 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Replacing ol along fractures. |
| Amphibole | 1 | Ol, ilmenite | Brown. Occurs surrounding primary ilmenite and sometimes ol. |
| Magnetite | 1 | Ol | |
| Amphibole | Tr | Cpx | Green. |

**COMMENTS:** Primary layering apparent as preferred orientation of cpx.

## THIN SECTION DESCRIPTION

**118-735B-40R-5 (Piece 2, 13-15 cm)**

**ROCK NAME:** Olivine-rich gabbro

**WHERE SAMPLED:**

**TEXTURE:** Adcumulate

**GRAIN SIZE:** Fine

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 14 | 15 | | | | Extremely fresh. |
| Plagioclase | 60 | 60 | | | | |
| Clinopyroxene | 24 | 24 | | | | |
| Hornblende | 1 | 1 | | | | Brown. Interstitial. Possibly secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | Tr | Cpx | Forms along edges of crystals. |
| Talc | 1 | Ol | |

**COMMENTS:** Rock is extremely fresh. Square opaques are partially oxidized.

## THIN SECTION DESCRIPTION

**118-735B-40R-5 (Piece 5, 49-52 cm)**

**ROCK NAME:** Feldspathic vein in gabbro

**WHERE SAMPLED:**

**TEXTURE:** Adcumulate (host)

**GRAIN SIZE:**

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| HOST | | | | | | |
| Plagioclase | 60 | 68 | | | | Some albitization. |
| Clinopyroxene | 10 | 27 | | | | Replaced by amphibole. |
| Olivine | 1 | 3 | | | | Tremolite pseudomorphs. Talc(?). |
| Ilmenite | 1 | 2 | | | | Replaced by sphene. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 5 | Plag | Also in vein. |
| Epidote | 3 | Plag | Blue interference colors. Also in vein. |
| Actinolite | 2 | Ol, plag, cpx | Spherulitic bundles. Late stage replacement. |
| Sphene | 1 | Ilmenite | |
| Hornblende | 17 | Cpx | Blue-green pleochroism. |

**COMMENTS:** Cpx is replaced by amphibole along microshears in host. Vein assemblage is blue-green amphibole, sodic plag, sphene, epidote, and quarte (?). Amphibole along microshears in host.

## THIN SECTION DESCRIPTION

**118-735B-41R-4 (Piece 1A, 20-27 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular, orthocumulate to mesocumulate

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.9 | 5.7 | 0.2-2.0 | | Anhedral | Rare kink band showing weak deformation, veined by black mineral (magnetite and clay?). |
| Plagioclase | 56.0 | 57.3 | 0.3-5.0 | | Anhedral | Some have concentric zoning. |
| Clinopyroxene | 27.8 | 33.6 | 0.2-4.0 | | Anhedral | Tiny opaque lamellae (ilmenite?) present. Vein between amphibole and plag replaced by amphibole. |
| Oxide | 0.4 | 0.4 | 0.02-1.0 | Fe-Ti | Anhedral | Inclusion in cpx, isolated large grains. It also intergrows with opx or brown hbd. |
| Orthopyroxene | 1.9 | 2.5 | 0.1-1.0 | | Anhedral | Rimming ol and cpx, locallly enclosing cpx with complex intergrowth. Isolated grains including cpx also occur. |
| Brown hornblende | 0.5 | 0.5 | 0.1-0.3 | | Anhedral | Rimming cpx, ol and Fe-Ti oxide. In cpx with opx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.0 | Ol | Brown, replacing ol from rim or along cracks. |
| Chlorite | 0.6 | Plag | Replacing plag as radial aggregate. |
| Actinolite | 0.9 | Cpx, ol | Replacing cpx near amphibole vein, rimming altered ol. |
| Brown-green hornblende | 6.0 | Vein | In vein, cutting primary structure, replacing cpx near the vein. |
| Mica | 0.8 | Ol | Replacing ol core with Fe-Ti oxide. |
| Fe-Ti oxide | 0.2 | | |

**COMMENTS:** Grain size variation defines 1-2cm thick layering. In coarser layer, cpx has average grain size of 2.5 mm, in finer layer, approximately 1.0 mm. Magmatic foliation is roughly perpendicular to the size-defined layering.
Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-41R-4 (Piece 1D, 68-70 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 64 | 65 | | | Anhedral | |
| Clinopyroxene | 24 | 25 | 1.0-3.5 | | Anhedral | Contains exsolution of opx and rod-like inclusions of opaques. |
| Opaques | Tr | Tr | | | | |
| Orthopyroxene | Tr | — | | | | Exsolution lamellae and small patches. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.5 | Ol | Along fractures. |
| Magnetite | 1 | Ol | |
| Talc/Tremolite | 0.5 | Ol | |
| Brown amphibole | Tr | Cpx | Patchy replacement of cpx, encloses primary opaques, occurs along grain boundaries |
| Green amphibole | 2 | Cpx | Fills small veins crosscutting plag, partially replacing Cpx. |

**COMMENTS:** Slide has a definite grain or foliation defined by elongate ol and cpx crystals which are preferentially aligned. Rock does not appear to be deformed; lacks granulation of crystals or apparent plastic deformation.

## THIN SECTION DESCRIPTION

**118-735B-41R-4 (Piece 1E, 78-82 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 44 | 50 | | | | |
| Clinopyroxene | 36 | 49 | | | | |
| Spinel | — | <1 | | Ilmenite/ magnetite | | |
| Orthopyroxene | <1 | 1 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 10 | Cpx, plag | Dark blue interference, lines cracks in plag. |
| Epidote | 1 | | Mixed with sphene? or carbonate in one area. |
| Actinolite | 4 | Plag, cpx | Fibrous, pale. |
| Hornblende | 2 | | Green, replaces cpx in one area. |
| Talc | <1 | Opx | |
| Magnetite | <1 | Opx | Reaction zone. |

**COMMENTS:** Pyroxene pseudomorphs have a fringed edge of actinolite and a core of spherulitic chlorite. Opx has half the lamellae replaced by chlorite. Cpx has opx lamellae similarly replaced. Other late opx is replaced by talc and magnetite. All the alteration is static; there is no deformation. Calcite? in ol pseudomorphs.

## THIN SECTION DESCRIPTION

**118-735B-42R-1 (Piece 3B, 35-38 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulate

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Plagioclase | 43 | 65 | | | |
| Clinopyroxene | 16 | 33 | | | |
| Orthopyroxene | 1 | 2 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 1 | Plag | Grains in plag, mixed with carbonate. Also in veins. |
| Chlorite | 4 | Plag | Spherulitic clumps, mixed with carbonate, also veins. |
| Albite | 20 | Plag | Along fractures in plag. |
| Epidote | 2 | Plag | Zoisite in plag, difficult to estimate. |
| Actinolite | 10 | Cpx, hbd | Green to colorless. |
| Sphene | Tr | | After ilmenite? Small grains. |
| Hornblende | 2 | Cpx | Brown-green. |
| Hornblende | 1 | Filling vugs | Blue-green euhedral laths. |
| Ilmenite | Tr | | Altering to sphene. |
| Magnetite | Tr | | In white-green amphibole replacing ol/opx. |

**COMMENTS:** Rock is pervasively broken along small cracks. Alteration is somewhat controlled by distribution of fractures. Not deformed.

## THIN SECTION DESCRIPTION

**118-735B-42R-2 (Piece 3D, 119-121 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8.1 | 10 | 0.5-1.5 | | Anhedral | Partially replaced by colorles amphibole, talc and magnetite. |
| Plagioclase | 77.7 | 78 | 0.5-5.0 | | Anhedral | |
| Clinopyroxene | 8.5 | 11 | 0.5-2.5 | | Anhedral | Contains patchy exsolution of opx. |
| Ilmenite | 1.0 | 1 | 0.1-0.2 | | Equant, anhedral | |
| Orthopyroxene | Tr | | | | | Exsolution from cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.1 | | In thin veins. |
| Magnetite | 0.9 | Ol | |
| Talc | 0.4 | Ol | |
| Green amphibole | 1.9 | Cpx | In thin veins and replacing cpx near veins. |
| Colorless amphibole | 0.4 | Ol | |
| Brown amphibole | Tr | Cpx | |

**COMMENTS:** Cpx shows some subophitic to ophitic texture enclosing plag, but more generally associated with ol.
Percentages based on 1144 point counts.

## THIN SECTION DESCRIPTION

**118-735B-42R-3 (Piece 1B, 9-14 cm)**

**ROCK NAME:** Gabbro norite
**WHERE SAMPLED:**
**TEXTURE:** Anhedral granular
**GRAIN SIZE:** 0.5-10.0mm
**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 60 | 60 | 0.5-10.0 | | Anhedral | |
| Clinopyroxene | 27 | 30 | 0.5-5.0 | | Anhedral | |
| Enstatite | 5 | 6 | 0.5-4.0 | | Anhedral | |
| Olivine | 3 | 4 | 0.2-3.0 | | Anhedral | |
| Opaques | 1 | 1 | | | Anhedral | |
| Brown hornblende | Tr | Tr | <0.1 | | Anhedral | Grown around Fe-oxide. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.5 | Ol | |
| Talc | 0.3 | Ol | |
| Amphibole | 0.2 | Ol | |
| Amphibole | 3 | Px | |
| Carbonate | 0.3 | Crack | Vein mineral. |
| Magnetite | 0.2 | Ol | |

**COMMENTS:** Several different amphiboles present, including clear, blue-green and brown varieties. Sample is size-graded from 3-4mm grain size to 1cm average, across the section.

## THIN SECTION DESCRIPTION

**118-735B-42R-4 (Piece 3B, 62-65 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular
**GRAIN SIZE:** Medium to coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 16 | 17 | 0.5-2.5 | | Anhedral | |
| Plagioclase | 53 | 55 | 0.5-2.0 | | Anhedral | |
| Clinopyroxene | 25 | 28 | 0.5-2.5 | | Anhedral | Has opaque, rod-like inclusions. |
| Opaques | Tr | Tr | | | | |
| Orthopyroxene | Tr | | | | | Exsolution and small patches in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Actinolite | 2 | | On most grain boundaries, particularly cpx. |
| Plagioclase | 2 | Plag | Neoblasts. |
| Magnetite | 0.5 | Ol | |
| Talc/Tremolite | 0.5 | Ol | |
| Brown amphibole | 1 | | Surrounding primary Fe-Ti oxides. |

**COMMENTS:** Thin zone of granulation, approximately 0.2 mm wide cross-cuts the thin section, but elsewhere crystals are relatively free of deformation.

## THIN SECTION DESCRIPTION

**118-735B-43R-1 (Piece 1B, 22-29 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 4 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 64 | 65 | 2.0-11.0 | | Anhedral | |
| Clinopyroxene | 29 | 30 | 1.0-8.0 | | Anhedral | Contains inclusions of opaques. |
| Opaques | 1 | 1 | | | | Ilmenite and magnetite? |
| Orthopyroxene | Tr | | | | | Exsolution from cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Replacing along fractures. |
| Brown hornblende | Tr | Cpx | Patchy replacement of cpx, surrounds primary ilmenite. |
| Green amphibole | 2 | Cpx | In thin vein, replacing cpx and rimming tremolite after ol. |
| Colorless amphibole | <1 | Ol | |
| Magnetite | <1 | | |

**COMMENTS:** Slide contains a contact between two slightly different average grain sizes ie. 2.0-5.0 mm and 5.0-10.0 mm. Cpx has a roughly equant or ovoid shape rather than being subophitic or ophitic. Thin amphibole vein crosscuts sample in coarser-grained area, replacing cpx and altering ol to tremolite, actinolite and magnetite. Elsewhere alteration is negligible.

## THIN SECTION DESCRIPTION

**118-735B-43R-1 (Piece 1J, 126-128 cm)**

**ROCK NAME:** Altered gabbro cut by vein

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Fine to medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3 | 1-2 | | Anhedral | Completely replaced. |
| Plagioclase | 48 | 56 | 0.3-3.0 | | Anhedral | Numerous filled cracks. |
| Clinopyroxene | 5 | 40 | 0.5-3.0 | | Anhedral | Replaced by green to brown hbd. |
| Ilmenite | 1 | 1 | 0.2-0.3 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | | Replacement of ol pseudomorphs. |
| Chlorite | 1 | Plag, vein | Pale. |
| Albite | 5 | Plag, vein | Few round crystals in vein, most in situ replacement. |
| Tremolite/Actinolite | 2 | | Bladed minerals in groundmass with talc. |
| Sphene | <1 | Vein | |
| Hornblende | 20 | Vein | Green to yellow pleochroism, euhedral prisms. |
| Clinopyroxene | 5 | Vein | High relief, colorless; could be an amphibole. |
| Talc | 2 | Ol | With magnetite. |
| Magnetite | 1 | Ol | With talc. |
| Hornblende | 10 | Cpx | Green to brown; on margins with plag. |

**COMMENTS:** Cut by hydrothermal vein. Note primary grain size varies, being medium-grained above hydrothermal and fine-grained below.

## THIN SECTION DESCRIPTION

**118-735B-43R-4 (Piece 3B, 64-66 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | 5 | 0.3-1.5 | | Anhedral | Sometimes in cpx. |
| Plagioclase | 60 | 61 | 0.2-2.0 | | Anhedral | |
| Clinopyroxene | 20 | 32 | 0.4-9.0 | | | Sometimes in clumps of 6-10 grains. |
| Spinel | 2 | 2 | 0.2-2.0 | | | All on one side of sample, large ones common in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Plag | Dusting, fine fractures in plag. |
| Actinolite | 9 | Cpx | Pale green, rimming cpx, mostly on one side of sample. |
| Hornblende | 2 | Cpx | Brown-green to brown, as patches on cpx, particularly rimming some oxides in cpx. |
| Talc/Tremolite | 1 | Ol | Aggregates replacing ol. |
| Opaque/Clay | 1 | Ol | Along fractures and replacing ol. |

**COMMENTS:** Opaques concentrated on one side; ol included in some of the opaques. Seems to be a weakly developed igneous lamination defined by plag orientation; undulose plag, minor deformation, spindle twins. Possibly a little opx in larger opx clumps; none positively identified.

## THIN SECTION DESCRIPTION

**118-735B-43R-4 (Piece 8B, 135-139 cm)**

**ROCK NAME:** Altered olivine-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular to anhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 5 | | | | Originally 0.2 mm grains. |
| Plagioclase | 57 | 65 | 1.0-7.0 | | Euhedral–anhedral | Altered to clays, some epidote. |
| Clinopyroxene | 15 | 25 | 1.0-5.0 | | Anhedral | Extensively altered to actinolite. |
| Oxide | 1 | 2 | 2.0 | | Anhedral | May be after ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 8 | Plag | Dusting, along fractures and grain boundaries. |
| Epidote | 5 | Plag | In granular zone. |
| Actinolite | 10 | Cpx | Also in veins and minor replacement of ol. |
| Sphene | Tr | | In granular zone. |
| Hornblende | Tr | Cpx | Brown. |
| Oxide | 1 | Ol | |
| Pyrite | Tr | | Between cpx, may be in part primary. |
| Talc/Tremolite | 3 | Ol | |

**COMMENTS:** A 1 cm, plag-rich granular zone cuts sample; fine-grained, granulated by deformation. Epidote contains rare sphene developed along zone Remainder of rock statically altered.

## THIN SECTION DESCRIPTION

**118-735B-44R-1 (Piece 2C, 47-49 cm)**

**ROCK NAME:** Gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** PTR

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 63 | .5-5 | | Subhedral | |
| Clinopyroxene | 20 | 35 | 1-3 | | Subhedral | |
| Orthopyroxene | 0 | 2? | 2-3 | | Subhedral | Completely replaced. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | Plag, chlorite | Light brown. |
| Chlorite | 15 | Plag | Colorless, anomalous interference colors, patchy. |
| Epidote | 5 | Plag | Irregular to prismatic, yellow-blue colors. |
| Actinolite | 10 | Cpx | Colorless prisms |
| Hornblende | 5 | Cpx | Green to brown |

## THIN SECTION DESCRIPTION

**118-735B-43R-4 (Piece 8B, 135-139 cm)**

**ROCK NAME:** Vein cutting metagabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 50 | | | | Partially altered to albite + epidote + chlorite. |
| Clinopyroxene | 15 | 30 | | | | Partially altered to amphibole. |
| Olivine | — | 20 | | | | Altered to talc + magnetite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | | Cpx | Bright green smectite(?). |
| Clays | <1 | Plag | First order birefringence, spherules. |
| Chlorite | 1 | Plag | Replaces plag in groundmass. |
| Albite | 20 | Plag | Along fractures in groundmass and 1% in vein. |
| Epidote | 1 | Plag | Blue interference colors, on composition boundary between clinozoisite and epidote. |
| Actinolite | 3 | Cpx | With tremolite, edges on cpx and little fractures. |
| Sphene | 1 | | Pink to yellow pleochroism, in vein. |
| Hornblende | 5 | Cpx | Deep green; vein margins and replacement. |
| Talc | 8 | Ol | Replaces ol; mixed with magnetite; in groundmass. |
| Clinopyroxene | 14 | Vein | Diopside. |
| Magnetite | 2 | | |

**COMMENTS:** Vein assemblage: fresh cpx, epidote, sphene (pink mineral), sodic plag, opaques and green-blue amphiboles along the margin. Includes plag-cpx symplectites. Amphibole is restricted to margins of veins and the groundmass.

## THIN SECTION DESCRIPTION

**118-735B-44R-1 (Piece 2L, 113-120 cm)**

**ROCK NAME:** Contact between olivine gabbro and ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 12 | 0.5-5.0 | | Anhedral | Many kink bands, locally recrystallized into smaller grains, altered into opaques and tremolite. |
| Plagioclase | 35 | 60 | 1.0-7.0 | | Subhedral | Veined by amphibole. |
| Clinopyroxene | 10 | 28 | 2.0-10.0 | | Anhedral | No (001) lamellae, commonly rimming ol. |
| Opaque | 35 | 75 | 1.0-10.0 | | Euhedral–anhedral | Fe-Ti oxide and sulphide replaced by green mineral (? or chlorite). |
| Reddish-brown hornblende | Tr | Tr | 0.1 | | Anhedral | Replacing cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Opaque | Green, replacing opaque. |
| Clays | 1 | Ol | Yellowish green, filling ol cracks with opaque. |
| Chlorite | 1 | Opaque, plag | Pale green, replacing Fe-Ti oxide, veining plag. |
| Actinolite/Tremolite | 3 | Ol, cpx | Replacing ol and cpx. |
| Brown hornblende | 7 | Cpx | Replacing cpx, in places perfectly. |
| Fe-Ti oxide | 1 | Ol | Rimming ol with tremolite, also filling cracks in ol. |
| Mica (talc?) | 1 | Ol, plag | Rimming tremolite/actinolite aggregate after ol. |

**COMMENTS:** Contact between opaque-rich (Fe-Ti oxide and minor sulphide) gabbro and ol gabbro is fairly sharp.

## THIN SECTION DESCRIPTION

**118-735B-44R-2 (Piece 1A, 6-8 cm)**

**ROCK NAME:** Ilmenite- and magnetite-rich gabbro
**WHERE SAMPLED:**
**TEXTURE:** Hypidiomorphic granular
**GRAIN SIZE:**
**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | <1 | 1 | 0.2-0.4 | | Rounded | In pore spaces between opx and plag. |
| Plagioclase | 40 | 58 | 0.2-2.0 | | Rounded–anhedral | Included in ilmenite. |
| Clinopyroxene | 11 | 15 | 1.0-2.0 | | Anhedral | Interstitial type cpx, exsolution lamellae. |
| Orthopyroxene | 15 | 17 | 1.0-2.0 | | Anhedral | Oikocrystic. |
| Ilmenite | 10 | 11 | 0.05 | | Irregular | Symplectite intergrowths with opx containing exsolution lamellae of cpx. |
| Brown amphibole | 1 | 4 | | | Anhedral | Clear, strongly pleochroic intimately related to ilmenite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Brownish yellow. |
| Chlorite | 2 | Talc | Blue interference colors replacing talc close to opaque filling. |
| Hornblende | 3 | | Pale green to yellow-green replacing cpx. |
| Plagioclase | 11 | Plag | Neoblasts surrounding crushed larger plag. |
| Talc | 1 | Ol, opx | Intergrown with magnetite surrounding ol. |
| Magnetite | 1 | Ol | Minute grains; reaction products from ol and ilmenite replacement. |
| Tremolite | Tr | Talc | Needle growing on talc. |
| Leucoxene | <1 | Ilmenite | Cryptocrystalline. |
| Blue-green amphibole | Tr | Brown amphibole | Related to cracks. |
| Brown amphibole | 4 | Primary brown amphibole | Related to cracks, replacing px. |

**COMMENTS:** Symplectite of ilmenite with opx. Part of brown amphibole is primary. High temperature metamorphism followed by low temperature seawater hydrothermal circulation and alteration (clays). Two sets of exsolution lamellae: symplectites have magnetite and ilmenite alternating along distinct rods, some are tipped with pyrite, others have ilmenite spines surrounded by magnetite, some break down into nearly myrmekitic intergrowths.

## THIN SECTION DESCRIPTION

**118-735B-44R-2 (Piece 1J, 131-133 cm)**

**ROCK NAME:** Partially amphibolitized gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular (mesocumulate)
**GRAIN SIZE:** Fine to medium (0.5-2.0mm)
**OBSERVER:** NAT

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 1 | 5 | | | |
| Plagioclase | 50 | 55 | | | |
| Clinopyroxene | 25 | 40 | | | |
| Ilmenite/Magnetite | Tr | Tr | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | |
| Hornblende | 20 | Cpx, plag | Pale green-white on least altered side. |
| Magnetite | 2 | Ol, cpx | Associated with green-white amphibole. |
| Pyrite/Chalcopyrite | Tr | Ol, cpx | Reaction zones, largely replacing ol and portions of cpx. |

**COMMENTS:** Rock has a main fracture on one side of the slide, and many subordinate fractures lined with green amphibole. Two stages of green amphibole formation, reaction zone type (blue-green and white) and vein (dull green).

## THIN SECTION DESCRIPTION

**118-735B-44R-3 (Piece 5D, 78-81 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 12.5 | 15 | 2-10 | | Subhedral | Kink banding in some grains. |
| Plagioclase | 54.5 | 56 | 2-10 | An 68 | Subhedral-euhedral | Composition determined by Michel-Levy. |
| Clinopyroxene | 29.2 | 29 | 2-20 | | Subhedral | Oikocrysts enclosing plag and ol. |
| Orthopyroxene | 0.1 | Tr | 2 | | Anhedral | Rimmiing ol. Rare. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 0.2 | Plag | Fibrous intergrowths with margarite(?) and tremolite. |
| Tremolite/ actinolite | 1.9 | Ol | Forms reaction corona around ol. |
| Hornblende | 0.1 | Cpx | Rims cpx. |
| Margarite(?) | 1.5 | Plag | Micaceous mineral with talc-like appearance found on outer rims of reaction coronas around ol when ol is enclosed in plag. |

**COMMENTS:** Fresh, undeformed ol gabbro.
Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-45R-1 (Piece 1F, 48-51 cm)**

**ROCK NAME:** Ferrogabbro, olivine gabbro

**WHERE SAMPLED:** Contact between ferrogabbro and olivine gabbro

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| FERROGABBRO | | | | | | |
| Orthopyroxene | 9.2 } | 41 | | | Anhedral | Inverted pigeonite. |
| Clinopyroxene | 28.2 } | | | | Anhedal | |
| Plagioclase | 39.6 | 50 | | | Anhedral | |
| Ilmenite | 9.0 | 9 | | | Anhedral | Ilmenite/magnetite intergrowths. This percentage includes pyrite/pyrrhotite/chalcopyrite intergrowths. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| FERROGABBRO | | | |
| Plagioclase | 10.2 | Plag | |
| Amphibole | 1.3 | Cpx | Brown. |
| Amphibole | 2.5 | Cpx | Green. |

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| OLIVINE GABBRO | | | | | | |
| Olivine | 2.5 | 3 | 0.5-4.0 | | Anhedral | |
| Plagioclase | 60.8 | 61 | 1-6 | | Anhedral | |
| Clinopyroxene | 34.5 | 35 | 0.5-4.0 | | Anhedral | Exhibits a complex exsolution/intergrowth relationship between cpx and opx. |
| Orthopyroxene | 1.1 | 1 | | | Anhedral | Exsolution from cpx. |
| Ilmenite | 0.3 | Tr | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| OLIVINE GABBRO | | | |
| Clays | Tr | Ol | |
| Magnetite | 0.3 | Ol | |
| Amphibole | 0.2 | Cpx | Brown. |
| Amphibole | 0.3 | Cpx | Green. |

**COMMENTS:** Some granulation of feldspar at contact.
Cpx exsolving Fe-oxide (ilmenite?).
Percentages based on 1673 point counts in the ol gabbro, and 1034 point counts in the ferrogabbro.

## THIN SECTION DESCRIPTION

**118-735B-45R-2 (Piece 1B, 15-17 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 22 | 22 | 0.5-1.0 | | Anhedral | |
| Plagioclase | 50 | 50 | 1-4 | | Subhedral | |
| Clinopyroxene | 27 | 27 | 0.5-3.0 | | Anhedral | Subophitically enclosed plag, ol. Wraps around the margins of cpx (not a subophitic texture). |
| Ilmenite | 1 | 1 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Amphibole | Tr | Ilmenite, cpx | Around ilmenite and along grain boundaries of some cpx crystals. |

**COMMENTS:** This rock is extremely fresh.
There may be a crude primary layering defined by concentrations of ol.

## THIN SECTION DESCRIPTION

**118-735B-45R-4 (Piece 7, 136-140 cm)**

**ROCK NAME:** Hydrothermal vein through gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:**

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 5(?) | | | | Almost completely altered to talc and anthophyllite pseudomorphs. |
| Plagioclase | 10 | (?) | | | | |
| Clinopyroxene | 15 | (?) | | | | |
| Hornblende | 1 | 1 | | | Blebs | Inclusions in cpx. |
| Ilmenite | 4 | 6 | | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Chlorite | Pinkish, with sphene in vein. High relief. Also occurs with carbonate. |
| Carbonate | 1 | Vein | Occurs with clay. |
| Chlorite | 5 | Plag | Radial aggregates. Miarolitic? Also in coronas with actinolite. |
| Analcite | Tr | Plag | Rims on plag. Also in vein. |
| Epidote | 20 | Plag, cpx | Two varieties. |
| Actinolite/ Fe-Mg amphibole | 20 | Cpx, plag, ol | Needles, bladed, pale green to colorless. Fe-Mg amphibole is intergrown with actinolite. |
| Sphene | 2 | Ilmenite | Pink, euhedral crystals, intergrown with ilmenite. |
| Hornblende | 15 | Veins, cpx | Dark green to brown pleochroism. Rims on cpx. |
| Talc | 3 | Ol | Ol pseudomorphs. |
| Sulfides | 2 | | Large euhedral crystals. |
| Apatite | Tr | | |
| Diopside | Tr | Cpx | Intergrown with sphene. |

**COMMENTS:** Sphene-opaque in windowpane texture; also ilmenite-Fe sulfide-chlorite in trellis texture.
Opaques in vein with amphibole.
Diopside is intergrown with sphene.

## THIN SECTION DESCRIPTION

**118-735B-46x-2 (Piece 7B, 128-130 cm)**

**ROCK NAME:** Porphyroclastic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 35 | 74 | 1-1.0 | | Subhedral-anhedral | Recrystallized and slightly altered to epidote. |
| Clinopyroxene | 20 | 25 | 1-5 | | Anhedral | Slightly recrystallized and altered to green-brown hbd. |
| Oxide | 1 | 1 | 0.1-2 | | Anhedral | Streaks, elongated in the foliation. |
| Brown hornblende | Tr | Tr | 0.1 | | Anhedral | Irregular patches in cpx. |
| Quartz | Tr | (?) | | | | Primary? Subhedral grains, 0.2 mm. Unstrained. in fracture of cpx and in small clusters throughout the rock. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Plagioclase | 39 | Plag | Recrystallized neoblasts, 0.1-0.5 mm. |
| Clinopyroxene | 2 | Cpx | Recyrstallized neoblasts, 0.1-0.5 mm. |
| Green-brown hornblende | 13 | Cpx, brown hbd | Rims around cpx and euhedral crystals aligned in the foliation planes. |
| Epidote | Tr | Plag | Small needles in plag. |

## THIN SECTION DESCRIPTION

**118-735B-46R-3 (Piece 2D, 24-26 cm)**

**ROCK NAME:** Olivine bearing gabbro with mylaritic

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Fine to medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | (5-10) | 1.2-4 | | Anhedral | Faint sub-grain boundaries rarely altered to mica, tremolite, mica, talc, and clays |
| Plagioclase | 30-45 | (50-60) | 1.2-4 | | Anhedral-euhedral | Partially recrystallized. |
| Clinopyroxene | 20-25 | 25-30 | 1.5-4 | | Anhedral | Some recrystallization of cpx. Partially altered to green hbd. |
| Oxthopyroxene | 2-4 | (5) | 1.2-4 | | Anhedral | Some recrystallization of cpx. Partially altered to green hbd. |
| Fe-Ti oxide | 0-3 | (0-3) | 1.2 | | Anhedral | Rims around cpx and oxides. |
| Brown amphibole | 0-1 | (0-1) | 0.2 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Green hornblende | 7 | Opx, cpx, brown hbd | |
| Mica<br>Tremolite<br>Talc | 2.7 | Ol | In replacement aureoles. |
| Plagioclase | 5-30 | Plag | Recrystallized neoblasts. |
| Clinopyroxene | Tr | Cpx | Recrystallized neoblasts. |

**COMMENTS:** A mylonitic band separates two slightly different gabbros; one fine-grained, one medium-grained. The percent recrystallization increases in both directions towards the band

## THIN SECTION DESCRIPTION

**118-735B-46R-3 (Piece 10, 121-128 cm)**

**ROCK NAME:** Fe-Ti bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Fine to medium, locally coarse

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 4 | >5 | 0.1-0.3 | | Anhedral | Commonly accompanied by opaques. Forming a few ol-rich layers. Slight replacement by clay + magnetite. |
| Plagioclase | 58 | <59 | 0.1-0.3 | | Anhedral-subhedral | Rare crystals measure up to ≈10 mm. |
| Clinopyroxene | 27 | 31 | 0.1-2.0 | | Anhedral-subhedral | (001) and (100) exsolution lamellae are common. |
| Oxides | 5 | 5 | 0.05-3.00 | Fe-Ti | Anherdral | Locally rimmed by ol. |
| Orthopyroxene | Tr | Tr | 0.1-0.3 | | Anhedral | Patchy inclusions in cpx. Exsolution lamellae and rimming cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol | Dark yellowish brown. Replacing ol. |
| Chlorite | <1 | Plag | Green. Veins in plag. Also rimming actinolite aggregate and replacing cpx. |
| Actinolite | 2 | Cpx | Replacing cpx and brown-green hbd. |
| Hornblende | 2 | Cpx, opaques | Brown-green. Rimming cpx and opaques. |
| Mica | <1 | Ol | Talc(?). Replacing ol. |
| Fe-Ti oxide | <1 | Ol | Replacing ol with talc or with clays. |

**COMMENTS:** Opaque-rich and ol-rich layers (≈5 mm wide) are present parallel to foliation which is defined by elongated plag and cpx crystals. Opaques form a lense-shaped aggregate which is also parallel to the foliation. A coarse-grained area is present in the sample, perpendicular to the foliation. Deformation is weak: kink bands in ol, and minor recrystallization of plag.

## THIN SECTION DESCRIPTION

**118-735B-46R-4 (Piece 11, 109-113 cm)**

**ROCK NAME:** Opaque gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral-anhedral granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 56 | 58 | 9-20 | | Subhedral | Undulose extinction. Some grain boundary deformation. |
| Clinopyroxene | 19 | 29 | 7-27 | | Anhedral | Containing patches of brown hbd and opx. |
| Opaques | 13 | 13 | 2-10 | | Anhedral | Interstitial between plag and cpx; intergrown with cpx. |
| Sulfides | Tr | Tr | <1 | | | In opaques. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | In some fractures. |
| Chlorite | Tr | Cpx | Occurs around actinolite clots. Also in some veins. |
| Actinolite | 7 | Cpx | Replacing cpx. In veins cutting plag. |
| Hornblende | 3 | Cpx | Small patches in cpx. |
| Plagioclase | 2 | Plag | <0.1 mm neoblasts. |

**COMMENTS:** Some deformation. Distinct lamination may be in part igneous. Some grain boundary recrystallization. Percentages basad on 1600 point counts.

## THIN SECTION DESCRIPTION

**118-735B-47R-2 (Piece 3, 31-36 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 12 | | | | Largely invaded by chlorite, tremolite. |
| Clinopyroxene | 10 | 26 | <5.0 | | | With inverted pigeonite. |
| Pigeonite | 8 | 2 | <4.0 | | | With worm-like exsolution of cpx. |
| Ilmenite | 45 | 58 | | | Anhedral | Enriched zone of ferro-gabbro. |
| Brown amphibole | 3 | 2 | | | | Strongly pleochroic, related to ilmenite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Px | Brown dusting. |
| Chlorite | 6 | Plag | Grey birefringence color, replaced by tremolite/actinolite. |
| Actinolite | 18 | Px, plag | Colorless, pseudomorph after px, replaces chlorite after plag. |
| Brown amphibole | 3 | Px | Patches in partly amphibolitized intergrowth of opx and cpx. |
| Magnetite | 2 | Ilmenite | As streaks. |

**COMMENTS:** Tendency for opaque to develop symplectite with px. Plag + px + fluid reacted to produce chlorite . + tremolite/actinolite.

## THIN SECTION DESCRIPTION

**118-735B-47R-2 (Piece 8A, 102-104 cm)**

**ROCK NAME:** Hydrothermally altered Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Altered, slightly sheared

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 70 | 1.0-10.0 | | | Locally recrystallized, widely albitized. |
| Clinopyroxene | 12 | 30 | 1.0-10.0 | | | Widely replaced by green amphibole. |
| Fe-Ti oxide | 5 | 6 | 1.0-5.0 | | | Rimmed by sphene. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 16 | Plag | Along cracks in the plag; quite pervasive replacement. |
| Epidote | 4 | Plag. | Zoisite and clinozoisite; same might replace plag. Hydrothermal. |
| Sphene | 3 | Fe-Ti oxide | Rims around oxide and euhedral hydrothermal crystals in epidote-rich zones. |
| Green amphibole | 20 | Cpx | Hydrothermal. |
| Plagioclase | 10 | Plag | Recrystallized and crushed close to shear zone. |
| Blood red mineral | <1 | | Associated with sphene and rods of opaque mineral (rutile?). |

**COMMENTS:** A sub-vertical sheared zone approximately 1-2mm across, with crushing and some recrystallization of the plag. Epidote and sphene are preferentially recrystallized and appear undeformed in this crushed zone. The green amphibole is locally kinked.

**118-735B-47R-3 (Piece 2, 50-52 cm)**

## THIN SECTION DESCRIPTION

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:** Near a contact between Fe-Ti oxide and olivine gabbro
**TEXTURE:** Cumulate
**GRAIN SIZE:** Medium
**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6 | 7 | 1.0-6.0 | | Anhedral | Sometimes rims px. |
| Plagioclase | 65 | 65 | 1.0-10.0 | | Anhedral | Sometimes intergrown with ol. |
| Clinopyroxene | 27 | 28 | 1.0-10.0 | | Anhedral | Sometimes as rims around ol. |
| Orthopyroxene | <1 | ? | 0.2 | | | Found in one talc alteration zone. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol | |
| Actinolite | <1 | Plag | |
| Brown-green hornblende | 1 | Cpx | Rims around cpx. |
| Talc, opaque, mica | 1 | Ol | |

**COMMENTS:** Thin section was taken from a minicore, in which a contact between Fe-Ti gabbro and ol gabbro is present. Unfortunately, no contact present in the thin section. A bizarre intergrowth of ol and plag is present close to the contact (present in the thin section).

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**118-735B-47R-4 (Piece 5, 80-86 cm)**

## THIN SECTION DESCRIPTION

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Mesocumulate
**GRAIN SIZE:** Coarse
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6 | 8 | 0.2-4.0 | | Anhedral | Enclosed in cpx and intergranular. |
| Plagioclase | 46 | 47 | 0.2-5.0 | | Subhedral | Partially enclosed in cpx. |
| Clinopyroxene | 35.5 | 43 | 0.8-8.0 | | Anhedral | Subophitic-coarse, intergranular. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Plag | In fractures and veins. |
| Chlorite | 1 | Ol, cpx | Fine-grained aggregates around actinolite, tremolite, in veins. |
| Actinolite | 8 | Cpx | |
| Hornblende | 0.5 | Cpx | Minor brown patches. |
| Opaques | 1 | Ol | On fractures, probably a mixture of clays and opaques. |
| Talc/Tremolite | 1 | Ol | Fine-grained aggregates around olivines. |

**COMMENTS:**
Percentages based on 1910 point counts:

| | | |
|---|---|---|
| Plagioclase | 47.1 | (total) |
| Clinopyroxene | 33.8 | |
| Olivine | 10.3 | |
| Brown amphibole | 0.4 | |
| Tremolite | 1.0 | |
| Smectite | 0.4 | |
| Talc | 1.5 | |
| Chlorite | 2.4 | |
| Actinolite | 0.8 | |
| White mica | 0.7 | |
| Opaques | 1.0 | |

## THIN SECTION DESCRIPTION

**118-735B-68R-2 (Piece 9, 109-113 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Fine

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 0.5 – 0.5 | | Anhedral | Rimming opaque mineral in a coarse part. |
| Plagioclase | 44 | 45 | 0.1 – 2 | | Anhedral | Veined by amphibole. |
| Clinopyroxene | 29 | 40 | 0.1 – 2 | | Anhedral | (100), (001) Lamellae common. |
| Oxide | 5 | 5 | 0.1 – 1 | Fe-Ti | Anhedral | Accompanied by ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Green hornblende | 10 | Cpx, plag | Replacing cpx and filling veins in plag. |
| Brown hornblende | 1 | Ol | Primary? Rimming cpx. |
| Mica | 1 | Ol | Talc? Accompanied by opaque (Magretite) |
| Clay | 1 | Cpx | Brown, along crack in ol. |

**COMMENTS:** Size layering present. A fine (≈0.5 mm), 2 cm-thick layer is sandwiched by medium-grained (≈2 mm), foliated layers. Thick thin section.

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## THIN SECTION DESCRIPTION

**118-735B-48R-4 (Piece 6, 82-84 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 2 | 0.1-0.5 | | Anhedral | Enclosed by or rimming opaque, altered into brownish clay. |
| Plagioclase | 48 | 51 | 0.5-5.0 | | Anhedral | Recrystallized into smaller neoblast. |
| Clinopyroxene | 30 | 35 | 0.3-5.0 | | Subhedral–anhedral | Rarely enclose opx patches, comonly shows (001) exsolution. |
| Spinel/Fe-Ti oxide | 12 | 12 | 0.05-2.0 | | Euhedral–anhedral | Plag or cpx inclusions are euhedral (including sulphides). |
| Orthopyroxene | 1 | 2 | 0.1-0.5 | | Anhedral | Patches in cpx, Some are probably inverted pigeonite, which occurs in px aggregate. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Brown. |
| Chlorite | 2 | Plag | Green, veining and rimming plag. |
| Actinolite/Tremolite | 3 | Cpx, opx | Replacing cpx rim, also replaces cpx. |
| Brown-green hornblende | 2 | Cpx | Replacing cpx rim. |
| Biotite | Tr | | Reddish brown, occurs near opaque mineral. |

**COMMENTS:** Slightly deformed and shows porphyroclastic appearance. Opaque mineral, cpx and plag show preferred orientation, which is parallel to the deformation foliation.

## THIN SECTION DESCRIPTION

**118-735B-49R-1 (Piece 3B, 42-46 cm)**

**ROCK NAME:** Fe-Ti oxide

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.1 | 1.3 | 0.2-1.0 | | Anhedral | Mostly altered into yellowish-brown clay, always in contact with opaque. |
| Plagioclase | 49.5 | 51.5 | 0.4-10.0 | | Anhedral | Wavy extinction, locally recrystallized. |
| Clinopyroxene | 26.6 | 31.0 | 0.3-5.0 | | Subhedral-anhedral | Rarely containing opx clots, exsolution lamellae parallel to (001) and (100), showing complex intergrowth. |
| Fe-Ti oxide | 15.0 | 15.6 | 0.1-5.0 | | Anhedral-euhedral | Anhedral: encloses round cpx crystals. Euhedral: small inclusion in plag, cpx. |
| Orthopyrene (?) | 0.1 | 0.1 | 0.1-0.5 | | Anhedral | Enclosed by cpx. Some have (001) cpx lamellae. Inverted pigeonite? |
| Brown hornblende | 0.5 | 0.5 | 0.1-1.0 | | Anhedral | In cpx or rimming cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.8 | Ol | Yellowish dark brown, replacing ol along cracks. |
| Carbonate | 0.4 | Ol | Replacing core of ol. |
| Green hornblende/ actinolite | 6.4 | Cpx | Replacing cpx rim, also as clots or veinlets in plag. Some recrystallized neoblasts. |
| Plagioclase | 0.6 | Plag | Rimming cpx. |
| Mica or talc | Tr | Cpx | |

**COMMENTS:** Cpx has low-Ca pyroxene clots which show the same C-axis orientation as the host cpx. They commonly occur at the core of cpx, but rarely as isolated grains. Cpx has hematite or ilmenite exsolution lamellae. Weak shape orientation of plag, opaque and cpx is apparent. Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-49R-2 (Piece 1A, 89-91 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** OZA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 1 | 0.1-0.3 | | Anhedral | Rimming opaque, commonly between cpx and opaque, mostly replaced. |
| Plagioclase | 47 | 60 | 0.5-15.0 | | Subhedral–anhedral | Locally granulated, veined by carbonate and amphibole. |
| Clinopyroxene | 25 | 35 | 0.5-8.0 | | Subhedral–euhedral | (001) exsolution common, some have opx patches. |
| Fe-Ti oxide | 10 | 10 | 0.1-4.0 | | Anhedral | Some inclusions in cpx are euhedral. |
| Orthopyroxene Inverted pigeonite | 1.5 | 3 | 0.1-4.0 | | Anhedral | Patches in cpx, also large isolated grains among cpx, some grains show varying exsolution. |
| Reddish brown hornblende | 0.5 | 1 | 0.1-0.5 | | Anhedral | Primary? Commonly in contact with opaque or replacing cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Cpx, ol | Green when replacing cpx, brown when replacing ol. |
| Carbonate | 3 | Opx, ol | Replacing opx and ol. |
| Actinolite | 7 | Cpx, vein | Replacing cpx, in places perfectly, veining plag. |
| Hornblende | 5 | Cpx | Brown to green, replacing cpx. |

**COMMENTS:** Slightly deformed. Complex cpx intergrowths.

## THIN SECTION DESCRIPTION

**118-735B-50R-2 (Piece 1B, 43-47 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.1 | 0.5 | 0.2-0.6 | | Anhedral | Usually in or near oxide. |
| Plagioclase | 36.6 | 37 | 0.4–1.5 | | Subhedral–anhedral | Undulose, broken sutured margins. |
| Clinopyroxene | 15.8 | 38 | 0.2–5.0 | | Anhedral | Bent, broken, sutured boundaries with plag. |
| Oxide | 21.9 | 22.5 | 0.1-4.0 | | Anhedral | Poikilitically encloses ol. Cpx on large grains, interstitial or smaller. |
| Orthopyroxene | 1.0 | 2 | 1–3 | | Anhedral | Present at the core of cpx. (001) lamellae apparent. Inverted pigeonite? |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.4 | | Veins, fractures, small clots around oxides, ol. |
| Actinolite | 23 | Cpx | 21.7% after cpx, pale green patches and needles, 1.3% in veins and patches. |
| Hornblende | 1 | Cpx | Dark green, brown amphibole, well-crystallized, replacing cpx. |
| Talc | 0.1 | Ol | Around ol. |
| Tremolite | 0.1 | Ol | Needle-like aggregates replacing ol. |

**COMMENTS:** Slight deformation.

## THIN SECTION DESCRIPTION

**118-735B-50R-4 (Piece 1C, 87-89 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 59.0 | 73 | 1.5–8.0 | | Anhedral-euhedral | Some inclusion in cpx. |
| Clinopyroxene | 15.2 | 21 | 1.0-4.0 | | Anhedral | Contains exsolution of opx. |
| Ilmenite | 6.0 | 6 | 0.1-1.5 | | Anhedral, equant | Ilmenite-magnetite intergrowths, include some pyrite, pyrrhotite, chalcopyrite (approximately 0.5%). |
| Orthopyroxene | 0.1 | (?) | | | | Exsolution from low-Ca pyroxene? as well as thin exsolution in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 0.5 | Plag | Repalces plag generally around Fe-oxides. |
| Plagioclase | 14.2 | Plag | Neoblasts. |
| Brown amphibole | 1.5 | Cpx | Replaces along grain boundaries. |
| Green amphibole | 3.5 | Cpx, brown amphibole | Replaces brown amphibole and cpx, often around Fe-oxides. |

**COMMENTS:** Two px crystals show a complex exsolution relation probably reflecting a low-Ca pyroxene precursor (pigeonite?). This exsolution relationship includes a bleb-like inclusion of cpx and opx. The opx then has a wormy exsolution of cpx(?). Magnetite in ilmenite-magnetite intergrowths has ilmenite exsolution lamellae. Primary ilmenite is surrounded by later magnetite.
Percentages based on 591 point counts.

## THIN SECTION DESCRIPTION

**118-735B-51R-1 (Piece 1E, 102-104 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 58.5 | 70 | 0.5-8.0 | | Anhedral | Partially recrystallized to neoblasts, some plastic deformation. |
| Clinopyroxene | 12.0 | 23 | 2.0-6.0 | | Anhedral | Partially replaced by amphibole. |
| Ilmenite | 7.5 | 7 | 1.0-2.0 | | Anhedral | Ilmenite-magnetite intergrowths; includes pyrrhotite, pyrite chalcopyrite, although pyrrhotite is rare. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 0.5 | Plag | Partially replacing plag and filling some veins. |
| Plagioclase | 12.0 | Plag | Neoblasts. |
| Green amphibole | 7.0 | Cpx | Rimming brown amphibole, replacing cpx and in veins. |
| Brown amphibole | 2.0 | Cpx | This is not the same sort of amphibole associated with late stage magmatic processes and/or ilmenite ie. hbd zoned to green amphibole (actinolite) at rims. Occurs in veins. |
| Colorless amphibole | 0.5 | Cpx | May be very pale green amphibole. |
| Opaques | Tr | Cpx | In cracks and along cleavage. |

**COMMENTS:** Percentages based on 1014 point counts.

## THIN SECTION DESCRIPTION

**118-735B-52R-3 (Piece 2F, 121-123 cm)**

**ROCK NAME:** Meta-FeTi gabbro

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulate, cataclastic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 3 | | | | |
| Plagioclase | 50 | 60 | 0.5-3.0 | | | |
| Clinopyroxene | 25 | 37 | 2.0-5.0 | | | |
| Sulphides | <0.5 | | | | | Pyrite, chalcopyrite, pyrrhotite. |
| Oxides | <1 | | | | | Ilmenite-magnetite intergrowths. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Plag | |
| Albite | 9 | Plag | Anastomosing along fractures. |
| Actinolite | 2 | Ol | Green to colorless, tremolite. |
| Hornblende | 10 | Cpx | Green to brown. |
| Talc | 1 | | Bright green, speckled extinction. |
| Clinopyroxene | 1 | Cpx | Neoblasts; along grain boundaries with brown hbd. |

**COMMENTS:** Relicts of ol are coated by dark oxide. Margins of pseudomorphs are a skirt of green to colorless amphibole, other oxide patches contain a colorless mica. The latter may be primary ilmenite and have a skirt of green to brown pleochroic hbd similar to replacement phase for cpx. Some grains may be an altered ol enclosed by ilmenite. Part of the slide shows cataclastic deformation and recrystallization.

## THIN SECTION DESCRIPTION

**118-735B-52R-4 (Piece 3, 42-45 cm)**

**ROCK NAME:** Ilmenite gabbro

**WHERE SAMPLED:** Contact between leuco-microgabbro and ilmenite gabbro (see previous description)

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 45 | 5.0-10.0 | | Anhedral | |
| Clinopyroxene | 20 | 40 | 5.0-10.0 | | Anhedral | |
| Ilmenite | 15 | 15 | 2.0-4.0 | | Anhedral | Ilmenite-magnetite/sulphide intergrowths with rounded pyrite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Plag | |
| Epidote | <1 | | clinozoisite. Fills veins and some interstitial spaces |
| Plagioclase | 5 | Plag | Neoblasts and some replacement by another plag. |
| Green amphibole | 18 | | Actinolite fibres overgrown by blue-green amphibole |
| Brown amphibole | 1 | | |

**COMMENTS:** Gabbro adjacent to dike has reacted mineralogically. Plag near the vein is altering along anastomosing zones, presumably to the dike plag composition. Cpx has an overgrowth of pyroxene of the vein composition on the vein side. Cpx adjacent to the vein is most extensively altered, as is plag. Possibly pyrite in cpx exsolution lamellae

## THIN SECTION DESCRIPTION

**118-735B-52R-4 (Piece 3, 42-45 cm)**

**ROCK NAME:** Contact between leuco-microgabbro and ilmenite gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 75 | 75 | 1-2 | | Subhedral | |
| Clinopyroxene | 20 | 25 | 1-2 | | Anhedral | Very pale green color, probably Fe-rich composition. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Epidote | 1 | Veins | Clinozoisite rather than epidote; veins and interstitial. |
| Green amphibole | 4 | | Replaces cpx along grain boundaries. |

## THIN SECTION DESCRIPTION

**118-735B-52R-4 (Piece 4B, 88-94 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | | | | | | Completely altered to carbonate + opaque. |
| Plagioclase | 38.4 | 44 | 0.2-4.0 | | Subhedral | Undulose, granulated on margins. |
| Clinopyroxene | 24.9 | 42 | 0.5-4.0 | | Subhedral | Undulose, ragged edged. Opx patches present. |
| Oxide | 11.2 | 12 | 1.0-6.0 | Fe-Ti | Anhedral | Anhedral elongate grains, interstitial and enclosing cpx and plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.2 | | Cpx, veins. |
| Carbonate | Tr | | In pseudomorphs of cpx or ol, in and by oxide. |
| Chlorite | Tr | | With actinolite. |
| Actinolite | 15 | Cpx | 2-3% in veins through rock, remainder as patches and aggregates afetr cpx. |
| Hornblende | 5.6 | Cpx | Dark green and brown, well-crystallized, cpx rims and in veins. |
| Plagioclase | 4.2 | Plag | <0.1 mm neoblasts along margins of larger veins. |
| Talc/Tremolite | 0.5 | Ol | Largely talc aggergates after ol; very irregular patches. |

**COMMENTS:** Moderately deformed. Distinct foliation defined by elongation of pyroxene, amphibole, oxide. Extensive fine, grain boundary granulation and recrystallization; may be some opx, but not much. Amphibole is very dark green to brown, a high temperature vein-fill and cpx replacement. Percentages based on 1400 point counts.

## THIN SECTION DESCRIPTION

**118-735B-53R-1 (Piece 2L, 47-54 cm)**

**ROCK NAME:** Oxide-rich gabbro
**WHERE SAMPLED:**
**TEXTURE:** Foliated
**GRAIN SIZE:** Medium
**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | 3 | | | | |
| Plagioclase | 40 | 50 | | | | Deformed and recrystallized. |
| Clinopyroxene | 24 | 32 | | | | Recrystallized. |
| Ilmenite | 14 | 15 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ilmenite | Dark brown. |
| Chlorite | Tr | Plag | Intense bright green. |
| Albite | 1 | Plag | Occurs along anastamozing fractures. |
| Tremolite | 1 | Ol | Possibly mixed with an orthoamphibole. |
| Hornblende | 5 | Cpx, plag | Highly pleochroic. Brown cores and green rims. |
| Plagioclase | 9 | Plag | Neoblasts. |
| Cpx | 3 | Cpx | Neoblasts. |
| Talc | 1 | Ol | |

**COMMENTS:** Recrystallized zones of plag and cpx define a metamorphic foliation which is not really pervasive. The alteration is very heterogeneous across the slide.

## THIN SECTION DESCRIPTION

**118-735B-53R-3 (Piece 1G, 113-117 cm)**

**ROCK NAME:** Fe-Ti oxide-bearing gabbro
**WHERE SAMPLED:**
**TEXTURE:** Porphyroclastic
**GRAIN SIZE:** Variable, very fine to medium
**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 45 | <5 | | | Recrystallized. Porphyroclasts highly strained. Late cracks filled with ilmenite and green amphibole. |
| Clinopyroxene | 30 | 50 | <6 | | | Recrystallized. Porphyroclasts. Only partially replaced by green to brown amphibole. |
| Ilmenite | 3 | 5 | <3 | | Anhedral | Largely in intergranular space. Deformed along with the brown amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Epidote | Tr | Plag | Anomalous birefringence, pinkish in plane light. Partially recrystallized in actinolite. Dirty cyrstals as granoblasts and very small neoblasts in a vein, epidote + actinolite + magnetite. |
| Plagioclase | 35 | Plag | Neoblasts, <0.5 mm [illegible] size. |
| Clinopyroxene | 1 | Cpx | Neoblasts, <0.3 mm [illegible]e. |
| Amphibole | 14 | Cpx | Brown. Abundant, idic[illegible]. Occur wi[illegible]enite crystals in intergranular spaces. |
| Amphibole | 5 | Amphibole | Blue-green. Clearly ri[illegible] brown amp[illegible] |
| Ilmenite/ magnetite | 2 | Oxides | Mostly ilmenite with less [illegible] [illegible]ated with interstitial ilmenite and brown amphibole. |

**COMMENTS:** Veins bearing a deformation: greenschist assemblage: albite-epidote-actinolite-magnetite-sulfides.
See following description. Here, Ti-amphibole is largely derived from Ti diffusion from "abundant" oxides and from cpx.

## THIN SECTION DESCRIPTION

**118-735B-53R-5 (Piece 3, 40-43 cm)**

**ROCK NAME:** Gabbro, trondhjemite

**WHERE SAMPLED:** Contact between gabbro and trondhjemite

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Gabbro: coarse; trondhjemite: medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| GABBRO | | | | | | |
| Olivine | 2 | 10 | 5 | | Anhedral | |
| Plagioclase | 40 | 60 | 5-10 | | Anhedral | |
| Clinopyroxene | 10 | 15 | 3-8 | | Anhedral | Partially replaced by brown and green amphibole. |
| Ilmenite | 13 | 15 | 1-3 | | Anhedral | Percentage includes both ilmenite and magnetite, intergrowths with sulfides (pyrite-pyrrhotite-chalcopyrite). |
| Pyrite | Tr | Tr | | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| GABBRO | | | |
| Mica | 2 | Ilmenite/ magnetite | Phlogopite(?) and unidentified green mica (green phlogopite?). |
| Plagioclase | 20 | Plag | Neoblasts. |
| Amphibole | 5 | Ol | Colorless. |
| Amphibole | 5 | Cpx, amphibole | Green. Replaces brown amphibole. Also occurs in veins. |
| Amphibole | Tr | Cpx | Brown. |
| Magnetite | 3 | Ol | "Reaction zone" magnetite. |

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| TRONDHJEMITE | | | | | | |
| Plagioclase | 75 | 75 | 0.1-1.0 | | Euhedral-subhedral | Zoned. Blocky crystals with ≈0.02 mm wide overgrowths. |
| Quartz | 20 | 20 | 0.3-1.0 | | Anhedral | Largely appears interstitial to plag. |
| Biotite | 2 | 2 | 0.1-2.0 | | Anhedral | Encloses euhedral plag or appears interstitial. |
| Magnetite | 1 | 1 | 0.05-0.10 | | | |
| Clinopyroxene | 1 | 2 | 0.2-0.5 | | | Completely replaced by amphibole. Probably xenocrysts from gabbro. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| TRONDHJEMITE | | | |
| Chlorite | Tr | Biotite | Partially replaces biotite. |
| Amphibole | 1 | Cpx | Colorless. Replaces xenocrystic cpx. |
| Amphibole | Tr | Cpx | Green. Interstitial and replacing some cpx. |

**COMMENTS:** No primary ol in gabbro, but inferring from the concentrated masses of colorless amphibole + magnetite, it probably was originally present. Some cpx in trondhjemite may actually be primary. Subsequent to description above, a single cpx grain enclosed in euhedral plag crystal was observed. Adjacent to contact, ilmenite is surrounded by secondary mica, possibly phlogopite. This brown mica is replaced or is zoned to a greenish mica with low second order interference colors, $2V_x \approx 5°$.

Some secondary pyrite occurs in alteration zones.

## THIN SECTION DESCRIPTION

**118-735B-54R-1 (Piece 8B, 131-136 cm)**

**ROCK NAME:** Fe-Ti oxide-bearing olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 15 | 1-/-3 | | Subhedral-anhedral | Locally recrystallized. |
| Plagioclase | 34 | 54 | 2-10 | | Anhedral-subhedral | Locally recrystallized. |
| Clinopyroxene | 18 | 23 | 2-4 | | Subhedral-anhedral | Relatively fresh and undeformed. |
| Fe-Ti oxide | 5 | 5 | 1 | | Anhedral-subhedral | Occurs in rims of brown amphibole and mica. |
| Orthopyroxene | Tr | 1(?) | 1-2(?) | | Anhedral | Rimming ol. |
| Apatite | 2 | 2 | 0.1-0.5 | | Euhedral-subhedral | Commonly accompanied by opaques |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 2 | Plag, ol, opx | Small flakes in plag and in replacement rims of ol and opx. |
| Olivine | 2 | Ol | Recrystallized, 0.1 mm in size. |
| Hornblende | 2 | Cpx | Brown. Completely replaced by blue-green amphibole. |
| Plagioclase | 16 | Plag | Recrystallized, 0.1 mm in size. |
| Biotite rock. | 3 | | Hydrothermal (?) Brown. Occurs throughout the rock. |
| Amphibole | 3 | Hydrothermal(?) | Hydrothermal (?) Blue-green. Occurs throughout the rock, especially around ol and cpx. |
| Tremolite, opaques | 3 | Ol, opx | Replacement rims. |

**COMMENTS:** Moderate to extensive plastic deformation.

## THIN SECTION DESCRIPTION

**118-735B-54R-5 (Piece 5, 117-119 cm)**

**ROCK NAME:** Fe-Ti oxide

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0.5 | 3 | 0.2-0.8 | | Anhedral | Partially enclosed in cpx or wrapped around grain boundaries. |
| Plagioclase | 25 | 37 | 3-10 | | Anhedral | Partially recrystallized. |
| Clinopyroxene | 44.9 | 49 | 4-10 | | Anhedral | |
| Oxides | 9.7 | 10 | 1-3 | Fe-Ti | Equant | Percentage includes magnetite and ilmenite and pyrrhotite/pyrite/chalcopyrite intergrowths. |
| Orthopyroxene | 0.5 | <1 | | | | Exsolution from cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1.8 | Ol | Brown. |
| Clays | Tr | Cpx | Bright green, in cpx. |
| Plagioclase | 10.3 | Plag | Neoblasts. |
| Amphibole | 1.8 | Cpx | Brown. Patchy replacement of cpx. |
| Amphibole | 5.4 | Veins | Green. In veinlets. Some blue-green amphibole. |

**COMMENTS:** Ol occurs along cpx grain boundaries in chains of small crystals, often sandwiched inbetween cpx and Fe-Ti oxides

## THIN SECTION DESCRIPTION

**118-735B-54R-3 (Piece 7, 125-127 cm)**

**ROCK NAME:** Fe-Ti oxide-rich olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Weakly foliated

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** CAN

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 15 | 20 | 1–4 | | Anhedral | Kinked, slightly recrystallized. Replacement rims (see below). |
| Plagioclase | 22 | 45 | 1–4 | | Subhedral | Recrystallized, kinked. |
| Clinopyroxene | 12 | 25 | 1–4 | | Subhedral–anhedral | Partially replaced by brown amphibole. |
| Fe-Ti oxide | 10 | 10 | | Fe-Ti | Anhedral | Occurs in rims of brown amphibole and brown mica. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Brown, occurs along cracks in the ol. |
| Amphibole | 10 | Cpx, hbd | Brown-green to green. |
| Plagioclase | 23 | Plag | Recrystallized, 0.1–0.2 mm crystals. |
| Olivine | 3 | Ol | Recrystallized, 0.1–0.2 mm crystals. |
| Mica | Tr | Fe-Ti oxide(?) | Occurs in rims of Fe-Ti oxides. |
| Tremolite, opaques | 2 | Ol | Rims ol. |

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**COMMENTS:** Ol grains are rimmed by cpx and/or opx.
Plastic deformation imprint is clear: kinked and recrystallized plag and ol. But original magmatic character of the foliation is apparent in the preferred shape fabric of euhedral primary plag and cpx crystals.

## THIN SECTION DESCRIPTION

**118-735B-55R-1 (Piece 7, 124-128 cm)**

**ROCK NAME:** Amphibolitized Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Slightly crushed

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 5(?) | | | | Tremolite + opaque replacement alter ol(?). |
| Plagioclase | 35 | 50(?) | 1–6 | | Anhedral–subhedral | Crushed and replaced by actinolite. |
| Clinopyroxene | 25 | 40 | 1–5 | | Anhedral | Replaced by amphibole. |
| Orthopyroxene | 1 | 3(?) | | | | Replaced by amphibole. |
| Fe-Ti oxide | 2 | 2 | 1–3 | | Anhedral | Replaced by sphene. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Mafics | Oxidized mafic minerals (ol?). |
| Actinolite | 10 | Plag, mafics | Mafics (cpx). |
| Sphene | 1 | Fe-Ti oxide | Rims. |
| Hornblende | 1 | Cpx, oxides | Brown. Replaced by blue-green amphibole. |
| Amphibole | 20 | Plag, mafics | Blue-green. Replacing cpx, etc. |
| Tremolite, opaques | 4 | Mafics | Replacing ol(?). |

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**COMMENTS:** No significant plastic deformation but the rock was a bit crushed during replacement by hydrous phases.

## THIN SECTION DESCRIPTION

**118-735B-55R-2 (Piece 4, 101-105 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 1 | <3 | 0.1–1.0 | | Anhedral, polygonal | Often as rims around Fe-Ti oxides. |
| Plagioclase | 40 | 60 | 4 | | Euhedral | Partially recrystallized. |
| Clinopyroxene | 23 | 25 | 0.2–4.0 | | Anhedral | Partially replaced by amphibole and px. |
| Oxides | 7 | 7 | 0.2–4.0 | Fe-Ti | Anhedral–subhedral | |
| Orthopyroxene | 5 | ≤5 | 2–3 | | Anhedral | In cpx as patches. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | |
| Actinolite | 5 | Plag | |
| Hornblende | 2 | Cpx | Green. |
| Plagioclase | 15 | Plag | Recrystallized in small, <0.2 mm polygons. |
| Mica | Tr | Oxide | Brown. Occurs around Fe-Ti oxides. |
| Talc, tremolite, opaques | 1 | Ol | Rims ol and occurs in clusters. |

**COMMENTS:** The deformation is very limited to some recrystallization of plag. No pervasive foliation, and the magmatic, euhedral shape of plag is often preserved.

## THIN SECTION DESCRIPTION

**118-735B-55R-3 (Piece 5, 130-133 cm)**

**ROCK NAME:** Foliated gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 55 | 510 | | | | In clusters of small grains. |
| Plagioclase | 9 | 56 | | | | Almost completely recrystallized into polygons. |
| Clinopyroxene | 23 | 24(?) | 1–4 | | | Little grains replaced by actinolitic amphibole. |
| Orthopyroxene | 1 | 1(?) | | | | Small, rounded grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 5 | Plag, cpx | Small flakes around cpx and in plag mosaic. |
| Hornblende | <1 | Oxides | Brown. Occurs around Fe-Ti oxides. |
| Plagioclase | 43 | Plag | Recrystallized grains, 0.1 mm in size. |
| Olivine | <5 | Ol | Recrystallized grains, 0.1 mm in size. |
| Mica | Tr | Oxides | Brown. Replacing trace amounts of Fe-Ti oxides. |

**COMMENTS:** Moderate deformation. Recrystallized and kinked plag and ol crystals indicate that the foliation corresponds to plastic deformation. Deformation could be mistaken for a magmatic lamination. Possibly weakly deformed magmatic lamination.

## THIN SECTION DESCRIPTION

**118-735B-56R-2 (Piece 1B, 11-14 cm)**

**ROCK NAME:** Mylonitic Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Very fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3 | | | Anhedral | Primary ol is completely recrystallized. |
| Plagioclase | — | 64 | | | Anhedral | Primary plag is recrystallized with the exception of a few grains. |
| Clinopyroxene | 22 | 22 | | | Augen | A few recrystallized grains. |
| Orthopyroxene | 1 | 1 | | | Anhedral | Trails of cpx augens. Also disseminated in plag mosaic. |
| Fe-Ti oxides | 10 | 10 | | | Anhedral | Possibly primary Ilmenite + magnetite + pyrite widely dispersed. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 3 | Plag, ol, opx(?) | Small flakes in the mosaic. |
| Hornblende | Tr | Fe-Ti oxide | Brown. Rimming Fe-Ti oxides. |
| Plagioclase | 57 | Plag | Recrystallized grains, 50–200μm. |
| Mica | Tr | Fe-Ti oxides | Brown. Occasional flakes around Fe-Ti oxides. |
| Olivine | 7 | Ol | Recrystallized grains, 50–200μm. |
| Magnetite | Tr | Ol | Near ol in amphibole alteration rims. |

**COMMENTS:** Intense deformation with recrystallization of ol, plag, and opx. Virtually no replacement of cpx by amphiboles.

## THIN SECTION DESCRIPTION

**118-735B-56R-2 (Piece 14, 144-146 cm)**

**ROCK NAME:** Amphibolitized mylonitic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | | | | | None left. Possibly replaced by actinolite. |
| Plagioclase | — | 60 | | | | Entirely recrystallized. |
| Clinopyroxene | 15 | | | | | Rounded augen. |
| Orthopyroxene | 6 | | | | | Rounded augen. |
| Fe-Ti oxides | 10 | | | Fe-Ti | | Ilmenite and magnetite + traces of pyrite. Disseminated grains in rims of brown or green amphibole. Widely dispersed in granulated matrix. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 3 | Plag | In mesh with actinolite. Replacement of plag neoblasts and ol(?). |
| Actinolite | 24 | Cpx, plag, ol(?), opx | |
| Hornblende | 3 | Cpx, oxides, opx(?) | Brown. Replaced by actinolitic amphibole. |
| Plagioclase | 39 | Plag | Recrystallized grains, 0.05–1.00 mm in size. |
| Clinopyroxene | Tr | Cpx | Recrystallized grains, ≈0.05 mm in size. |

**COMMENTS:** Oriented thin section.
Intense plastic deformation was followed by static replacement of primary mineral by hydrous phases actinolite and chlorite.

118-735B-56R-3 (Piece 26, 101-103 cm)

## THIN SECTION DESCRIPTION

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** PTR

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | 63 | .1-2 | | | Partially recrystallized neoblasts. |
| Clinopyroxene | 15 | 35 | 1-9 | | | Replaced by brown hbd. |
| Fe-Ti oxide | 2 | 2? | 1-5 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Plag | Replacing plag with zoisite. |
| Epidote/zoisite | 2 | Plag | Replacint plag. |
| Actinolite | Tr | Hbd | |
| Sphene | Tr | Hbd? | |
| Hornblende | 20 | Cpx | Brown with minor green, replaces cpx. |
| Plagioclase | 20 | Plag | Small neoblasts between larger crystals. |
| Albite | 1 | Plag | Along small veins. |

**COMMENTS:** Fe-Ti gabbro. Sight granulation of plag. Cpx extensively rimmed and replaced by brown to dark green amphibole. High temperature replacement?

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118-735B-57R-2 (Piece 3E, 135-138 cm)

## THIN SECTION DESCRIPTION

**HOCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 2 | 5 | ≈1 | | Anhedral |
| Plagioclase | 52 | 57 | | | Anhedral |
| Clinopyroxene | 15 | 38 | <2 cm | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Plag | Some along fractures in ol. |
| Chlorite | 8 | Cpx | Possibly after ol. |
| Albite | 3 | Plag | Minor. Occurs along fractures in plag. |
| Actinolite | 15 | Cpx | |
| Talc/tremolite | 2 | Ol | |
| Oxides | 1 | Ol | |

**COMMENTS:** Slight deformation: undulose extinction in plag, spindle twins, and slight annealing and suturing of boundaries.

## THIN SECTION DESCRIPTION

**118-735B-57R-3 (Piece 10, 44-48 cm)**

**ROCK NAME:** Albitized gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 3(?) | | | | Replacement zones with the usual replacement products of ol. |
| Plagioclase | 30 | 80 | | | | Slightly crushed. The crushed fragments are classified with the secondary mineralogy. |
| Clinopyroxene | 5 | 15-20 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | < 1 | Ol(?) | Cores of replacement zones. |
| Chlorite | < 1 | Plag | Patches close to replacement zones. |
| Albite | 30 | Plag | Replaces plag along the microfractures. |
| Epidote | < 1 | Plag | Epidote, zoisite, and clinozoisite. In veins and in crushed zones in plag. Hydrothermal(?). |
| Hornblende | 15 | Cpx | Brownish green. Hydrothermal(?). |
| Plagioclase | 10 | Plag | Crushed grains. |
| Mica | < 1 | | Brown. Two or three 1 mm grains in the crushed plag. Hydrothermal(?) |
| Mica, tremolite, opaques | ≤ 2 | Ol(?) | Clays + opaques and tremolite + white mica + actinolite are likely replacement products of ol. |

**COMMENTS:** Protolith probably ol-bearing gabbro. Intense albitization of plag and amphibolitization of cpx. Very little crushing.

## THIN SECTION DESCRIPTION

**118-735B-58R-1 (Piece 9, 44-46 cm)**

**ROCK NAME:** Altered gabbro

**WHERE SAMPLED:**

**TEXTURE:** Altered, highly crushed

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 40 | | | | | Crushed, patches of carbonate. |
| Clinopyroxene | 17 | | | | | Replaced by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | 15 | Plag | Patches especially in plag. |
| Epidote (zoisite) | 8 | Plag | In plag crushed area. |
| Brown-green amphibole | 20 | Cpx | |

**COMMENTS:** Carbonate, epidote, etc., are probably more hydrothermal than in situ replacement. Highly crushed. Section contains huge hole, therefore modal percentages are probably inaccurate.

## THIN SECTION DESCRIPTION

**118-735B-58R-2 (Piece 1C, 33-35 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Faint magmatic lamination

**GRAIN SIZE:** Medium to fine

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 15 | 1.0-4.0 | | Anhedral | Replaced by tremolite and opaques. |
| Plagioclase | 77 | 78 | 1.0-2.0 | | Euhedral-subhedral | Fresh, undeformed. |
| Clinopyroxene | 5 | 7 | 1.0-3.0 | | Anhedral | Replaced by some amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Brown hornblende | 1 | |
| Tremolite | 3 | Ol |
| Opaque | 2 | Ol |
| Green amphibole | 2 | Cpx, plag, brown amphibole |

**COMMENTS:** No plastic deformation; the observed foliation is a magmatic lamination. Oriented thin section.

## THIN SECTION DESCRIPTION

**118-735B-58R-3 (Piece 1F, 107-114 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Subhedral granular
**GRAIN SIZE:** Coarse
**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9.8 | 10.4 | 2.0-12.0 | | Anhedral | Kink bands. |
| Plagioclase | 57.8 | 58 | 2.0-15.0 | | Subhedral | |
| Clinopyroxene | 30.6 | 30.8 | 2.0-12.0 | | Subhedral | Cpx-cpx intergrowths, bleb-like exsolution in some grains, curved twin lamellae. |
| Fe-Ti oxide | 0.2 | 0.2 | 0.1-1.5 | | Anhedral | Interstitial, forms symplectic intergrowth with opx. |
| Orthopyroxene | 0.5 | 0.5 | 1.0 | | Anhedral | Rims around ol and interstitial. |
| Sulphide | Tr | Tr | <0.1 | | Anhedral, blebs | Near grain boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | Deep green clay veining ol. |
| Actinolite/tremolite | 0.5 | Ol | Rims around ol and filling veins. |
| Magnetite | 0.2 | Cpx, ol | Blebs in cpx and associated with tremolite replacing ol. |
| Margarite? | 0.2 | Plag | Associated with tremolite reaction rim around ol. |

**COMMENTS:** Primary Fe-Ti oxide, opx and hbd are late-stage crystallization products of trapped liquid.
Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-59R-4 (Piece 1C, 29-35 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular
**GRAIN SIZE:** Very coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7 | 7 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 52.5 | 53 | 1.0-10.0 | | Anhedral | Subhedral where enclosed in cpx. |
| Clinopyroxene | 40 | 40 | 2.0-8.0 | | Anhedral | Subophitically encloses plag. Locally rimming ol. |
| Opaque | 0.1 | Tr | 0.1-0.5 | Ilmenite, sulfides | Anhedral | Inclusions in plag. and rimming ol, cpx. |
| Orthopyroxene | Tr | Tr | | | Anhedral | Exsolution from cpx. and rimming ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | |
| Magnetite | 0.1 | Ol | Veining ol. |
| Green amphibole | 0.2 | Cpx | |
| Brown amphibole | Tr | Cpx | |

**COMMENTS:** Mesocumulate. Very fresh.
Percentages based on 2003 point counts.

## THIN SECTION DESCRIPTION

**118-735B-59R-3 (Piece 1D, 70-72 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Cumulate

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6 | 6 | 0.5-2.0 | | Anhedral | Very slightly altered. |
| Plagioclase | 74 | 74 | 2.0-6.0 | | Subhedral-euhedral | Almost unaltered. |
| Clinopyroxene | 20 | 20 | 2.0-6.0 | | Anhedral | Almost unaltered. |
| Opaques | Tr | Tr | 0.1-0.3 | | Subhedral-anhedral | Inclusions in plag and interstitial to plag and cpx. |
| Hornblende | Tr | Tr | 0.05-0.10 | | Anhedral | Brown, patches in cpx. |
| Orthopyroxene | Tr | Tr | 0.2 | | Anhedral | Rimming ol and cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Actinolite | <1 | Plag, cpx |
| Tremolite | <1 | Ol |
| Opaques | <1 | Ol |

**COMMENTS:** Cpx(?) rims along the ol-plag grain boundaries. No deformation.

## THIN SECTION DESCRIPTION

**118-735B-59R-3 (Piece 1D, 70-72 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral equigranular

**GRAIN SIZE:** 0.5-10.0 mm

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7 | 7 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 55 | 55 | 0.5-10.0 | | Anhedral-subhedral | |
| Clinopyroxene | 38 | 38 | 1.0-10.0 | | Intergranular-subophitic | Granular to subophitic. |
| Sulphides | <1 | <1 | <0.1 | | Blebs | Interstitial and in cpx. |
| Orthopyroxene | Tr | Tr | | | Anhedral | Interstitial lenses on grain boundaries. |
| Amphibole | Tr | Tr | | | Anhedral | Interstitial lenses on grain boundaries. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Actinolite | <1 | Plag |
| Tremolite | <1 | Ol |
| Magnetite | <1 | Ol |

## THIN SECTION DESCRIPTION

**118-735B-60R-1 (Piece 1B, 18-20 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral equigranular

**GRAIN SIZE:** 0.5-10.0mm

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 15 | 15 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 55 | 55 | 1.0-7.0 | | Anhedral - subhedral | |
| Clinopyroxene | 30 | 30 | 0.5-10.0 | | Subophitic | Subophitic. |
| Sulphides | <1 | <1 | <0.1 | | Blebs | Interstitial to plag, ol and cpx and as inclusions in cpx. |
| Orthopyroxene | Tr | Tr | 0.1-0.3 | | Anhedral | Rimming cpx and ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Talc | Tr | Ol | |
| Magnetite | Tr | Ol | |

**COMMENTS:** Very fresh olivine gabbro.

## THIN SECTION DESCRIPTION

**118-735B-60R-1 (Piece 1E, 80-83 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 5 | 5.0-12.0 | | Anhedral | |
| Plagioclase | 65 | 65 | 1.0-15.0 | | Subhedral-euhedral | |
| Clinopyroxene | 30 | 30 | 4.0-15.0 | | Anhedral | Subophitically to ophitically encloses plag. |
| Orthopyroxene | Tr | | | | | Occurs as thin lamellae and small patches in cpx. |
| Opaques | Tr | | | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Replaces along fractures. |
| Chlorite | Tr | | In patch of actinolite replacing cpx. |
| Actinolite/tremolite | Tr | Ol | Alteration at crystal boundaries. |
| Magnetite | Tr | Ol | |
| Brown amphibole | Tr | Cpx | |
| Actinolite | Tr | Cpx, plag | |

**COMMENTS:** Mesocumulate.

## THIN SECTION DESCRIPTION

**118-735B-61R-1 (Piece 3A, 81-83 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Very coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 5 | 1.0-3.0 | | Anhedral | Occasionally surrounds plag subophitically. |
| Plagioclase | 75 | 75 | 1.0-8.0 | | Subhedral | |
| Clinopyroxene | 20 | 20 | 2.0-8.0 | | Anhedral | Ophitically encloses plag. |
| Ilmenite | < 1 | | | | | Exsolution from cpx. |
| Orthopyroxene | < 1 | | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | | Replacing ol along crosscutting fractures. |
| Magnetite | < 1 | Ol | In alteration haloes around crystal. |
| Talc | < 1 | Ol | In alteration haloes around crystal. |
| Brown amphibole | < 1 | Cpx | Replaces patches in cpx and surrounds primary ilmenite. |

**COMMENTS:** Cpx shows complex intergrowth/exsolution texture.
Percentages based on 1467 point counts:

| | | |
|---|---|---|
| Plagioclase | 63.5 | |
| Clinopyroxene | 17.3 | |
| Olivine | 14.1 | |
| Brown amphibole | 0.4 | |
| Smectite | 0.4 | |
| Opaques | 1.0 | In the following proportions:<br>60% Pentlandite<br>37% Chalcopyrite<br>2% Pyrite<br>1% Magnetite |
| Talc | 1.7 | |
| Chlorite | 1.2 | |

## THIN SECTION DESCRIPTION

**118-735B-61R-1 (Piece 3A, 85-87 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5.7 | 6 | 1.0-3.0 | | Anhedral | Partially altered to talc and magnetite. |
| Plagioclase | 53.7 | 54 | 1.0-8.0 | | Subhedral | |
| Clinopyroxene | 37.6 | 40 | 2.0-8.0 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Clays | 0.2 | Ol |
| Talc | 0.1 | Ol |
| Magnetite | 0.6 | Ol |
| Brown amphibole | 0.7 | Cpx |
| Green amphibole | 1.3 | Cpx |

**COMMENTS:** Cpx exhibits a complex texture of exsolution of opx and intergrowth between adjacent crystals. Brown amphibole in trace amounts replacing cpx appears to associated with the exsolution texture in some way. Ol often has a thin layer of cpx around it, separating the ol from plag.
Percentages based on 1035 point counts.

## THIN SECTION DESCRIPTION

**118-735B-62R-1 (Piece 3A, 91-94 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7.9 | 8 | 2-8 | | Anhedral | Interstitial. Sometimes rimming cpx. |
| Plagioclase | 58.6 | 59 | 0.2-18.0 | | Anhedral | Some adcumulus growth. |
| Clinopyroxene | 31.7 | 33 | 2-12 | | Anhedral | Subophitic to ophitic. Inclusions of plag and rare ol. |
| Oxides | Tr | Tr | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol, cpx | In fractures. |
| Actinolite | 1.2 | Cpx | Rims along cleavage. |
| Talc/tremolite | 0.3 | Ol | Replacing ol, occuring with disseminated oxides. |
| Amphibole | 0.3 | Cpx | Clear blebs, intergrowths. Possibly part of a primary cpx intergrowth. |

**COMMENTS:** Percentages based on 1800 point counts.
No granulation, but plag has undulose extinction and some spindle twins. Ol is kinked.

## THIN SECTION DESCRIPTION

**118-735B-62R-3 (Piece 3B, 104-106 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 5 | 0.2-2.0 | | Anhedral | Intergranular. |
| Plagioclase | 43 | 44 | 0.2-5.0 | | Anhedral | |
| Clinopyroxene | 37 | 50 | 0.5-5.0 | | Anhedral | Intergranular to subophitic, rarely subhedral. |
| Spinel | 1 | 1 | 1.0 | | Anhedral | Associated with an ol pseudomorph, but probably primary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | | Veins, fractures in cpx ano ol pseudomorphs. |
| Chlorite | <1 | Ol | With talc and tremolite. |
| Actinolite | 8 | Cpx | Fibrous rims on cpx, filling 0.1-0.2mm wide veins. |
| Talc/tremolite | 2 | Ol | |
| Amphibole | 5 | Cpx | Clear patches with blebby exsolution intergrown with cpx; could be a primary intergrowth. These patches have extinction angles less than 20°, suggesting they are an amphibole. |

**COMMENTS:** Minicore end: undulose plag with a few tapering twins.

## THIN SECTION DESCRIPTION

**118-735B-63R-3 (Piece 3C, 80-82 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 11 | 0.5-10.0 | | Anhedral | Intergrown between plag-kinks. |
| Plagioclase | 66 | 66 | 1.0-12.0 | | Anhedral | |
| Clinopyroxene | 15 | 23 | 2.0-8.0 | | Anhedral | Intergranular, rarely ophitic, enclosing only plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | | Along fractures in ol, dusting plag. |
| Actinolite | 7 | Cpx | Patchy replacement on rims. Fibrous, fine replacement along cleavages. |
| Talc/tremolite | 1 | Ol | |
| Opaques | Tr | Ol | |

**COMMENTS:** Weak lamination defined by plag orientation.

## THIN SECTION DESCRIPTION

**118-735B-63R-5 (Piece 5A, 126-130 cm)**

**ROCK NAME:** Olivine metagabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5.9 | 10.0 | | | Anhedral | |
| Plagioclase | 59.0 | 61.2 | | | Subhedral–euhedral | Recrystallized at grain boundaries and in narrow shear zones. |
| Clinopyroxene | 24.9 | 28.8 | | | Subophitic | Numerous opaque and amphibole inclusions in cpx. |
| Opaque | Tr | Tr | | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.3 | Ol | Dark green clay. |
| Carbonate | Tr | Vein | Filling fracture around which plag is albitized. |
| Chlorite | 0.6 | Plag | |
| Albite | 1.6 | Plag | Associated with veins running through plag. |
| Zoisite | Tr | Plag | |
| Actinolite/Tremolite | 3.3 | Ol | Forms reaction coronas around ol. |
| Hornblende | 3.9 | Cpx | Forms rims around cpx and symplectically intergrown with cpx margins. |
| Magnetite | 0.5 | Ol | In association with tremolite. |

**COMMENTS:** Most significant feature is the common symplectite (wormy) intergrowth between amphibole and cpx at the margins of cpx.

## THIN SECTION DESCRIPTION

**118-735B-63R-6 (Piece 2B, 28-30 cm)**

**ROCK NAME:** Amphibolitized olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Slightly crushed

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 10 | 2.0-4.0 | | Anhedral | Extensively replaced. |
| Plagioclase | 40 | 60 | 2.0-4.0 | | Subhedral | Locally crushed with very small grains. |
| Clinopyroxene | 10 | 30 | 2.0-4.0 | | Anhedral | Replaced by actinolite and chlorite and extensively replaced by amphibole. |
| Orthopyroxene | <1 | | 0.1-1.0 | | Subhedral | Small grains in alteration rims of ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | <1 | Ol | Unstrained, cores of ol crystals. |
| Chlorite | <1 | Plag | Patches on plag. |
| Actinolite | 10 | Plag, ol | In alteration rims of ol and around plag. |
| Green hornblende | 22 | Cpx | Replaces cpx and in little crosscutting veins. |
| Plagioclase | 10 | Plag | Very small(<0.05mm) grains in crushed zones. |
| Tremolite | 5 | Ol | In alteration rim of ol. |
| Talc | <1 | Ol | In alteration rim of ol. |
| Opaques | <1 | Ol | In alteration rim of ol. |

**COMMENTS:** The rock is crushed; crushing produces kinks and fractures in the plag and in the amphibole. It does not produce a pervasive foliation.

## THIN SECTION DESCRIPTION

**118-735B-64R-2 (Piece 1C, 54-56 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:**

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6 | 8 | 0.8-3.0 | | Anhedral | Intergranular or intergrown with plag. |
| Plagioclase | 58 | 60 | 0.8-4.0 | | Subhedral | Some adcumulus growth. |
| Clinopyroxene | 30 | 32 | 1.0-4.0 | | Anhedral | Intergranular to subophitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | | On cleavages and fractures in cpx and ol, in some veins through plag. |
| Chlorite | 1 | Ol | Rim on ol alteration. |
| Actinolite | 2 | | Minor cpx alteration, filling veins. |
| Talc/tremolite | 2 | Ol | |
| Opaques | Tr | Ol | Associated with talc and tremolite. |

**COMMENTS:** Ol is altered with rims of talc/tremolite, with fine associated opaques, then rimmed by chlorite, often growing radially out from the pseudomorph. Both plag and cpx are somewhat undulose; plag often euhedral when included in cpx.
Thin section is cut from the end of a minicore.

## THIN SECTION DESCRIPTION

**118735B-64R-4 (Piece 1H, 73-76 cm)**

**ROCK NAME:** Altered gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 60 | .5-3 | An 65 | | Twinned. |
| Clinopyroxene | 10 | 40 | 1-3 | Augite | | Oikocrysts surround plag. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 5 | Plag | Associated with epidote and diopside. |
| Sodic, plagioclase | 3 | | Clear rims on twinned primary plag (An 20). |
| Epidote | 1 | Plag? | Clinozoisite; blue birefringence. |
| Actinolite | 15 | Plag, cpx | |
| Plagioclase | 20 | Plag | Extensive replacement; An 40, untiwinned. |
| Pyroxene | 15 | Vein, cpx | Diopside in veins and replacing primary augite euhedral grains. |

**COMMENTS:** Extensive medium temperature alteration and fracturing. One of the few rather extensive "skarn" assemblages in these rocks: clinozoisite-chlorite-diopside-sphene- plag.

## THIN SECTION DESCRIPTION

**118-735B-65R-3 (Piece 1D, 54-58 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Poikilitic to subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9.0 | 10.0 | 2.0-5.0 | | | Some kink bands in ol. |
| Plagioclase | 54.6 | 55.0 | 2.0-10.0 | | | Zoned concentrically. |
| Clinopyroxene | 34.5 | 34.5 | 2.0-10.0 | | | Cpx-cpx intergrowths. Oikocrysts enclose plag and ol, some grains exhibit blebby exsolution. |
| Fe-Ti oxide | 0.2 | 0.2 | 0.5-2.0 | | | |
| Hornblende | Tr | Tr | <1 | | | Rim around cpx. |
| Orthopyroxene | 0.2 | 0.2 | <1 | | | |
| Apatite | Tr | Tr | <1.0 | | Rounded | One grain seen next to an opaque. |
| High relief mineral | Tr | Tr | <1.0 | | Euhedral | One grain near apatite, inclined extinction. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | Deep green clay. |
| Chlorite | 0.2 | Plag | |
| Actinolite/Tremolite | 0.8 | Ol | Reaction coronas around ol. |
| Hornblende | Tr | Cpx | Blebs in cpx. |
| Margarite(?) | 0.2 | Plag | Most commonly forms rim around ol reaction coronas. |
| Magnetite | 0.1 | Ol | Associated with tremolite. |

**COMMENTS:** Zoned plag, intercumulus oxides, hbd, opx and rare apatite suggest a moderate (15%) amount of trapped liquid. Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-66R-2 (Piece 7A, 86-88 cm)**

**ROCK NAME:** Altered gabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:**

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 2 | 1.5 | | | None left. |
| Plagioclase | 50 | 58 | 4.0 | | Anhedral—subhedral | |
| Clinopyroxene | 15 | 40 | — | | | Fragments in originally 4.0 mm grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Cpx, plag | Replacing cpx in ol(?) pseudomorphs, fractures in plag. |
| Chlorite | 5 | Ol, cpx | Commonly in clear amphibole, opaque clots. |
| Albite | 5 | Plag | Developing along fractures through plag. |
| Epidote | <1 | | Small grains 0.2 mm. |
| Amphibole | 15 | Cpx | Clear amphibole, in one case with blebby exsolution. |
| Oxides | <1 | | Scattered, <0.1 mm, associated with possible ol pseudomorphs. |

**COMMENTS:** Extensive low temperature alteration.

## THIN SECTION DESCRIPTION

**118-735B-66R-3 (Piece 8B, 66-68 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 48 | 70 | 4.0 | | | Lined with albite. |
| Clinopyroxene | 3 | 30 | | | | Small fragments in amphibole, clots after cpx |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 10 | Plag, cpx | After cpx in fractures. |
| Carbonate | 1 | | |
| Chlorite | 3 | Cpx | Associated with actinolite. |
| Albite | 10 | Plag | |
| Epidote | 10 | | Along shear zones. |
| Actinolite | 15 | Cpx | Clear, patchy and fibrous aggregates after cpx. |

**COMMENTS:** 0.5-1.0 mm wide shear zones cut sample, with granulated plag along them. Epidote developed primarily along these little shears and in veins.

## THIN SECTION DESCRIPTION

**118-735B-66R-3 (Piece 2L, 134-138 cm)**

**ROCK NAME:** Porphyroclastic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 15 | | 1.0-3.0 | | Anhedral | Anhedral fragments. |
| Clinopyroxene | 10 | | 1.0-3.0 | | Anhedral | Anhedral fragments. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 5 | | Dusting plag, mixed in groundmass. |
| Albite | 10 | Plag | Replacing large plag on veins and as neoblasts. |
| Epidote | 3 | | In mosaic groundmass? |
| Actinolite | 3 | Cpx | Incipient replacement of cpx. |
| Plagioclase | 35 | Plag | Neoblasts, small granulated grains. |
| Clinopyroxene | 19 | Cpx | Neoblasts, small granulated grains. |

**COMMENTS:** No good foliation developed. May be quite a bit more epidote than noted. Proportions very approximate.

## THIN SECTION DESCRIPTION

**118-735B-67R-3 (Piece 1H, 74-78 cm)**

**ROCK NAME:** Olivine-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subophitic

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2.0 | 4.1 | 3.0-4.0 | | Anhedral | Intergranular. |
| Plagioclase | 65.3 | 67 | 1.0-11.0 | | Euhedral–anhedral | |
| Clinopyroxene | 19.5 | 28.9 | 2.0-8.0 | | Anhedral | Intergranular to subophitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.7 | Ol, cpx | On fractures and cleavages. |
| Chlorite | 0.6 | Ol | Outside of alteration halos. |
| Actinolite | 9.0 | Cpx | 1.4% in veins. |
| Hornblende | Tr | Cpx | Brown, on cpx margins, probably a primary phase. |
| Talc/tremolite | 2.0 | Ol | |
| Opaques | 0.2 | Ol | With talc/tremolite. |
| Clear amphibole | 0.7 | Cpx | Blebby, clear patches intergrown with cpx. |

**COMMENTS:** Percentages based on 1700 point counts.

## THIN SECTION DESCRIPTION

**118-735B-68R-2 (Piece 1B, 16-21 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 13.4 | 14.1 | | | | 1cm plag-ol intergrowths. |
| Plagioclase | 64.0 | 65.0 | | | | Normally zoned rim (0.1mm), intercumulus plag strongly zoned. |
| Clinopyroxene | 20.7 | 20.7 | | | | Multiple cpx-cpx intergrowths, cpx oikocrysts enclose both ol and plag, some cpx has wormy exsolution (?) blebs. |
| Orthopyroxene | 0.2 | 0.2 | | | | |
| Sulphide | Tr | Tr | | | | Primary intercumulus phase. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.0 | Plag | Found on margins of plag. |
| Hornblende | Tr | Cpx | |
| Tremolite | 0.4 | Ol | Reaction rims around ol. |
| Magnetite | 0.3 | Ol | Associated with tremolite. |

**COMMENTS:** From textural relationships ol and plag crystallized together before cpx. Percentages based on 1048 point counts.

## THIN SECTION DESCRIPTION

**118-735B-68R-3 (Piece 5, 62-64 cm)**

**ROCK NAME:** Hydrothermal vein in gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 0 | ? | | | Euhedral- | Round pseudomorphs. |
| Plagioclase | 30 | ? | | | subhedral | Cross by numerous micro gractures filled with amphibore. |
| Clinopyroxene | 5 | 20 | | | Anhedral | Partially altered to amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | | | Small vein that cuts lagre vein. |
| Chlorite | 4 | Plag | Radial bundles. |
| Epidotite | 5 | Vein | Clinozoisite. |
| Hornblende | 5 | | Green to brown rims on cpx and cracks in plag. |
| Sphene | 1 | Ilmenite | |
| Tremolite? | 10 | Ol, cpx, plag | Bladed amphibole, pale to colorless in radial bundles. |
| Plagioclase | 15 | Vein, plag | Anastomozing network adjacent to vein and in vein. Sodic. |
| Diopside | 10 | Vein, cpx | Euhedral to barrel-shaped. |
| Oxide | 5 | Ol? | Fine-grained masses with amphibole. |

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## THIN SECTION DESCRIPTION

**118-735B-69R-3 (Piece 5C, 86-92 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.5 | 7 | 2.0-3.0 | | Anhedral | |
| Plagioclase | 55 | 55 | 2.0-12.0 | | Anhedral | |
| Clinopyroxene | 30.5 | 38 | 4.0-12.0 | | Anhedral | Ophitic. |
| Oxide | Tr | Tr | | | | Primary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Cpx, ol | |
| Chlorite | 0.2 | Ol | Some in veins. |
| Actinolite | 3.0 | Cpx | A little in veins. |
| Hornblende | 0.2 | Cpx | Primary interstitial liquid. |
| Talc/tremolite | 2.5 | Ol | |
| Oxides | 0.5 | Ol | With talc, tremolite. |
| Clear amphibole | 4.6 | Cpx | Blebby, clear patches intergrown with cpx. |

**COMMENTS:** Percentages based on 2000 point counts.

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## THIN SECTION DESCRIPTION

**118-735B-69R-3 (Piece 5C, 86-92 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3.5 | 7 | 1.0-8.0 | | Anhedral | Interstitial, subrounded. |
| Plagioclase | 53.5 | 54 | 1.0-10.0 | | Subhedral–anhedral | Some adcumulus growth. |
| Clinopyroxene | 31.5 | 39 | 2.0-16.0 | | Anhedral | Subophitic to intergranular. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | | Plag | Filling small fractures. |
| Actinolite | 3.9 | Cpx | Rimming cpx, small amount in veins. |
| Talc/tremolite | 2.5 | Ol | |
| Opaque | 0.5 | Ol | Occurs along fractures with clay. |
| Clinopyroxene | 4.6 | Cpx | Large clear patches with complex blebby exsolution, amphibole (?) after cpx. Could be primary cpx. |

**COMMENTS:** The clear patches with exsolution may be a primary px intergrowth.

## THIN SECTION DESCRIPTION

## 118-735B-69R-4 (Piece 4C, 138-140 cm)

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 0.6-8.0 | | Anhedral | Partially encloses plag, some kinked. |
| Plagioclase | 55 | 55 | 0.7-10.0 | | Anhedral | Euhedral inside cpx. |
| Clinopyroxene | 25 | 35 | 3.0-9.0 | | Anhedral | Subophitic, encloses plag only and not ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Along fractures, probably with actinolite. |
| Clinopyroxene amphibole | 10 | Cpx | Could be primary. |
| Talc/Tremolite | 2 | Ol | |
| Opaques | <1 | Ol | Fine oxides in ol alteration. |

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**COMMENTS:** The cpx has intergrown patches, both within single grains and growing between grains, clear cpx or amphibole with dense wormy exsolution of opx or an amphibole. Looks like a secondary texture, but could be primary or deuteric.

## THIN SECTION DESCRIPTION

## 118-735B-69R-5 (Piece 1D, 42-45 cm)

**ROCK NAME:** Altered gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** 287 KEM—

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| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 30 | 3-10 | | Anhedral-subhedral | |
| Clinopyroxene | 60 | 70 | 5-10 | | Anhedral-subhedral | Some of the cpx may be secondary, associated with the hydrothermal vein. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clay | Tr | Plag | |
| Chlorite | Tr | Plag, cpx | Also in thin veins. |
| Plagioclase | 18 | Plag | Sodic. |
| Green amphibole | 1 | Cpx, plag | In thin veins. |
| Brown amphibole | 1 | Cpx | |
| Colorless amphibole | <1 | plag | |
| Sphene | Tr | | In hydrothermolly altered area. |

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**COMMENTS:** Gabbro with extensive low temperature alteration. No evidence of primary ol or opx. Sample appears to have a cpx-rich, plag-rich layering on a small scale, but hard to tell through the alteration. Alteration is locally very extensive (75-80%), but elsewhere as little as 10%. Cpx shows unusual exsolution/intergrowth texture.

## THIN SECTION DESCRIPTION

**118-735B-70R-1 (Piece 3A, 80-84 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2.0 | 4 | 1.0-8.0 | | Anhedral | Intergranular. |
| Plagioclase | 57.0 | 58 | 1.0-10.0 | | Subhedral — anhedral | |
| Clinopyroxene | 33.0 | 38 | 2.0-12.0 | | Anhedral | Subophitic to poikilitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.7 | Plag, cpx | Along fractures in plag and cpx. |
| Actinolite | 5.5 | Cpx | Rimming cpx, along cleavage. |
| Hornblende | 0.1 | | Brown amphibole. |
| Talc/tremolite | 1.6 | Ol | After ol. |
| Opaque | 0.1 | Ol | |
| Amphibole | | Cpx | Clear patches with blebby exsolution, cpx or amphibole after cpx? Could be a primary texture. Probably accounts for ≈5% of the total cp |

**COMMENTS:** Percentages based on 1700 point counts.

## THIN SECTION DESCRIPTION

**118-735B-70R-1 (Piece 5B, 105-107 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 35 | 65 | 2.0-12.0 | | Anhedral | Altered porphyroclasts. |
| Clinopyroxene | 15 | 35 | 2.0-16.0 | | Anhedral | Ubicutously altered along cleavages. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 8 | Cpx, plag | Along fractures and cleavages. |
| Albite | 5 | Plag | Clear rim on large porphyroclasts. |
| Actinolite | 10 | Cpx | Fine, dense aggregates after cpx, along fractures, rims. |
| Hornblende | 2 | Cpx | Some dark green-brown amphibole after cpx. |
| Plagioclase | 25 | Plag | <0.2 mm neoblasts, may be in part albite. |

**COMMENTS:** Moderate deformation, plag and cpx in a matrix of fine recrystallized plag with extensive low temperature alteration. No strong foliation. This is probably a fragment of one of the gabbroic breccias.

## THIN SECTION DESCRIPTION

**118-735B-70R-2 (Piece 2, 8-10 cm)**

**ROCK NAME:** Metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 20 | 55(?) | 54 | | Anhedral | Shards of primary plag. |
| Clinopyroxene | 2(?) | (?) | | | | Relict. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 5 | | |
| Sodic plagioclase | 35 | Plag | Recrystallization along fractures and cleavages. |
| Diopside | 18 | Cpx | Clear, subhedral grains and cpx margins. |
| Sphene | 15 | | Grains measure up to 1 mm. Dark red rutile(?), hematite(?) clots in interior of some crystals. |
| Opaques | 5 | | Small dark red to opaque clots in sphene. Rutile(?), hematite(?), clay(?). |
| Rutile | 5 | Cpx | Yellow aggregates. |

**COMMENTS:** Skarn assemblage: diopside-rutile.
Section is plucked, up to 40% void space with dirty glue spots. No way to make reasonable modal estimates.

## THIN SECTION DESCRIPTION

**118-735B-71R-2 (Piece 2A, 82-84 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Medium

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7 | 7 | 1-4 | | Anhedral | Fresh. Small rims of tremolite and opaque. |
| Plagioclase | 63 | 63 | 1-5 | | Subhedral | Fresh. Very little alteration to actinolite. |
| Clinopyroxene | 28 | 28 | 1-4 | | Anhedral | Fresh. Very little alteration to brown amphibole. Also occurs as rims around ol. |
| Orthopyroxene | <1 | <1 | 0.1 | | Anhedral | Rimming ol and cpx. |
| Hornblende | <1 | <1 | 0.1 | | Anhedral | Pale brown rimming ol, cpx, and opaque. |
| Opaque | Tr | Tr | 0.1 | | Subhedral-anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING |
|---|---|---|
| Actinolite | Tr | Cpx, plag |
| Tremolite | Tr | Ol |
| Opaques | Tr | Ol |

**COMMENTS:** Oriented thin section.
Very fresh, undeformed.

## THIN SECTION DESCRIPTION

**118-735B-71R-2 (Piece 3C, 129-131 cm)**

**ROCK NAME:** Pyroxene gabbro with hydrothermal vein

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | (?) | | | | |
| Plagioclase | 20 | 60 | 1-4 | | Subhedral-euhedral | |
| Clinopyroxene | 15 | 35 | 1-6 | | | Oikocrysts. |
| Oxides | <1 | (?) | | Ti-Fe, sulfides? | | Primary or associated with hydrothermal vein. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Epidote | 2 | Vein | Epidote + zoisite + clinozoisite. |
| Actinolite | 24 | Vein, cpx, plag | Acicular amphibole in vein, possibly actinolite. |
| Amphibole | 39 | Vein | Colorless, very low birefringence. Forms large flowers. |
| Mystery mineral | Tr | Vein | Possibly sphene. Very high birefringence, high relief. Long, 2 mm grain. |

**COMMENTS:** The vein is at least 1 cm thick. No trace of deformation.

## THIN SECTION DESCRIPTION

**118-735B-71R-3 (Piece 1A, 0-5 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular, mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 6.1 | 8 | 1-8 | | Anhedral | Enclosing plag. Kinked crystals.<br>Undulose extinction. |
| Plagioclase | 54.2 | 55 | 1-10 | | Euhedral-anhedral | |
| Clinopyroxene | 30.6 | 37 | <12 | | Subhedral | Large oikocrysts with chadacrysts of plag. |
| Spinel | <0.2 | 0.2 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Veins | In veins and fractures. |
| Chlorite | <<0.2 | Plag | Veins through plag. |
| Actinolite | 2.0 | Cpx | On rims, lining cleavages. |
| Hornblende | Tr | Cpx | Brown. |
| Talc/tremolite | 2.5 | Ol | Occurs with some fine oxides. |
| Clinopyroxene(?) | 4.2 | Cpx | Clear patches with exsolution, intergrown with cpx. Possibly primary intergrowth. |

**COMMENTS:** Percentages based on 1815 point counts.
Plag crystals are euhedral, where as chadacrysts are anhedral with some cumulus growth.

## THIN SECTION DESCRIPTION

**118-735B-71R-3 (Piece 5, 104-107 cm)**

**ROCK NAME:** Olivine-bearing gabbro with hydrothermal vein

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 5 | 3 | | Anhedral | Rimmed by tremolite ± talc and mica. |
| Plagioclase | 30 | 60 | 4 | | Subhedral | Replaced by actinolite. |
| Clinopyroxene | 15 | 35 | 4 | | Anhedral | Replaced by green-brown hbd. |
| Fe-Ti oxides | Tr | Tr | 1.5 | | Subhedral | Looks primary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Plag | Small patches. |
| Epidote | 3 | Veins | Epidote-clinozoisite. |
| Actinolite | 25 | Ol, plag, veins | Acicular amphibole. Seems to grow in altered plag, rendered isotropic somehow? |
| Sphene | Tr | Veins | |
| Hornblende | 22 | Cpx, veins | Brown-green. Replaces cpx and fills in main vein and small veinlets through the rock. |
| Tremolite, talc, colorless mica | 3 | Ol | Replacement rims. |

**COMMENTS:** This rock is not deformed.

## THIN SECTION DESCRIPTION

**118-735B-72R-2 (Piece 1D, 56-62 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8.2 | 9 | 1-5 | | | Some kink bands in ol. |
| Plagioclase | 65.2 | 65 | 2-10 | An 68-72 | | |
| Clinopyroxene | 26.1 | 26 | 1-10 | | | Cpx-c px intergrowths. Pinkish exsolution blebs in sections cut parallel to (001). |
| Hornblende | Tr | Tr | <1 | | | As blebs in cpx and rims around cpx. |
| Orthopyroxene | Tr | Tr | <1 | | Anhedral | Rare rims around ol. |
| Opaques | 0.2 | 0.2 | <0.1-1.0 | | Anhedral | Interstitial and cpx, ol margins. |
| Sulfides | Tr | Tr | <0.1 | | Anhedral | At margins of cpx, ol. Sometimes associated with oxide, but generally isolated. |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING | COMMENTS |
|---|---|---|---|
| Tremolite/ actinolite | 0.4 | Ol | Forms rare pseudomorphs after ol. |
| Magnetite | Tr | Ol | In association with tremolite. |
| Margarite(?) | 0.1 | Plag | Highly birefringent mineral found at grain margins next to ol relicts. |

**COMMENTS:** Percentages based on 2000 point counts, on a large thin section.
Plag composition estimated by Michel-Levy method.
Opaques, hbd, and opx, in addition to cpx and plag, are crystallization products of intercumulus liquid. The amount of trapped liquid is possibly as low as 10–15%.

## THIN SECTION DESCRIPTION

**118-735B-72R-4 (Piece 4, 57-59 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic to mylonitic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 25 | 44 | 2-6 | | Flattened | Porphyroclasts. |
| Clinopyroxene | 33 | 55 | 4-8 | | Ovoid | Porphyroclasts. |
| Spinel | 1 | 1 | 0.5 | | | Large grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ilmenite | Hematite-stained. |
| Carbonate | Tr | Veins | In veins with diopside. |
| Chlorite | Tr | Cpx | Mixed with actinolite, paralle[illegible] foliation. |
| Plagioclase | Tr | Plag | Sedic. Anastomozing vein. |
| Epidote | Tr | Plag | Pistacite; associated with sphene, veins, plag. |
| Actionolite | 14 | Plag, cpx | Green to colorless; fibrous or lath-like. |
| Sphene | 1 | Ilimenite | Very coarse-grained. |
| Hornblende | 8 | Cpx | Green to brown pleochroic. Rims and pseudomorphs. |
| Plagioclase | 15 | Plag | Neoblasts in mosaic; recrystallized. |
| Sulfides | Tr | | Partially oxided; with chlorite and sphene. |
| Diopside | 1 | Veins | |
| Ilmenite, magnetite | 2 | | Concentrations with plag neoblasts; rods in cpx. |

**COMMENTS:** Diopside veins are paralled to foliation. Looks like plastic deformation is followed by movement of lower temperature fluids (epidote-chlorite-sphene) into mylonite zone.

## THIN SECTION DESCRIPTION

**118-735B-72R-6 (Piece 5, 106-108 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 5 | 5 | 2-5 | | Anhedral | |
| Plagioclase | 60 | 60 | | | Subhedral | Cumulus crystals. |
| Clinopyroxene | 35 | 35 | 1-7 | | Anhedral | Oikocrysts, probably larger than 7 mm. |
| Opaques | Tr | Tr | | | | Probably ilmenite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Magnetite | Tr | Ol | |
| Amphibole | Tr | Cpx | Brown. Patchy and along grain boundaries. |

**COMMENTS:** Contains examples of complex recrystallization/exsolution/intergrowth textures between adjacent cpx crystals.

## THIN SECTION DESCRIPTION

**118-735B-73R-1 (Piece 3B, 54-57 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 4.0 | 5 | 0.3–1.0 | | Anhedral |
| Plagioclase | 41.2 | 42 | 0.6–6.0 | | Anhedral |
| Clinopyroxene | 39.7 | 53 | 2–8 | | Anhedral |
| Spinel | Tr | Tr | 0.1–0.2 | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | |
|---|---|---|---|
| Clays | 0.6 | Cpx, plag | Fine veins in cpx and plag. |
| Actinolite | 1.9 | Cpx | Rimming cpx. Also in veins. |
| Talc/tremolite | 1.2 | Ol | Occurs with opaques, and some clay. Rimming ol and along ol fractures. |
| Amphibole | 11.4 | Cpx | 1–8 mm patches. Very clear grains, either new cpx or amphibole with colorless to pale brown lamellae and wormy blebs of another amphibole in it. These complicated patches replace the original cpx. |

**COMMENTS:** Coarser-grained than 118–735B–73R–3 (Piece 4A, 73–75 cm). No big oikocrysts–more ophitic to subophitic cpx including both ol and plag chadacrysts, and intergrown with cpx. A complex replacement of cpx by large clear patches of another cpx or amphibole with exsolution or intergrowths of a pale colored amphibole (both as regular lamellae and blebs). Ol is a little more abundant in the portion of the thin section which was not point counted. Ol occasionally occurs as thin rims between cpx and plag.
Percentages based on 1200 point counts.

## THIN SECTION DESCRIPTION

**118-735B-73R-3 (Piece 4A, 73-75 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Meso-adcumulate

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 5 | 0.5–2.0 | | Anhedral | Locally intergrown with cpx. |
| Plagioclase | 45 | 45 | 0.3–4.0 | | Subhedral - anhedral | Intergrown with cpx and ol. |
| Clinopyroxene | 49 | 50 | 0.3–4.0 | | Anhedral-subhedral | Often in clumps of grains. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 2 | Ol | Occurs along fractures with oxides. Also in veins. |
| Chlorite | Tr | Ol | Rimming ol. |
| Actinolite | 1 | Cpx | In fractures in cpx. |

**COMMENTS:** Thin section is from the end of a minicore.
Sample was quite torn up in manufacture. Ol crystals are kinked. Some cpx crystals are bent. Plag has somewhat undulose extinction. Probably one third to one half of the cpx crystals have complex exsolution blebs of opx + trace amounts of hbd. Cpx with exsolution blebs is intergrown with cpx without blebs. There are twinned grains: one side has complex exsolution blebs and the other side is free of them.

## THIN SECTION DESCRIPTION

**118-735B-73R-5 (Piece 4, 74-78 cm)**

**ROCK NAME:** Oxide-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | — | 1(?) | | | | Completely altered to tremolite. |
| Plagioclase | 35 | 35 | 0.5–1.0 | | Anhedral–subhedral | Interlocking. |
| Clinopyroxene | 20 | 40 | 0.5–8.0 | | Anhedral | Subophitic, enclosing plag + oxide. |
| Oxides | 20 | 20 | 1–8 | | Anhedral | Intergrown with cpx. |
| Amphibole | 2 | 2 | 0.2–0.8 | | Anhedral | Small brown amphibole rimming cpx and oxides. |
| Orthopyroxene | 2 | 2(?) | 0.2–0.5 | | Subhedral | Small grains and lamellae in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 19 | Cpx | Pale green, after cpx. 1–2% filling pervasive fracture network. |
| Hornblende | 1 | Cpx | Dark green to brown patches around cpx. |
| Tremolite | 1 | Ol(?) | Small tremolite aggregates that are possibly ol or opx replacements. |

**COMMENTS:** There may be an opx here (not pigeonite). The brown amphibole is common, often as small grains or rims between cox and oxides, and at their junctures.

## THIN SECTION DESCRIPTION

**118-735B-74R-2 (Piece 2A, 38-40 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular to poikilitic

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM/MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 22 | 23 | 1–12 | | Anhedral | Enclosing plag. Symplectite texture. |
| Plagioclase | 70 | 71 | 0.7–8.0 | An 47 | Euhedral–anhedral | Cumulus. |
| Clinopyroxene | 5 | 6 | 0.2–1.5 | | Anhedral | Thin interstitial stringers. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | < 1 | Ol, plag, veins | Replacing margins of ol, filling veins, and in fractures in plag. |
| Actinolite | 1 | Cpx | Interstitial to plag, partially rimming cpx. |
| Talc | < 1 | Ol | Occurs with tremolite. |
| Tremolite | 1 | Ol | Aggregates after ol. |
| Oxides | < 1 | Ol | Small grains in ol pseudomorphs. |

**COMMENTS:** Two large ol grains enclosing or partially enclosing plag. Smaller interstitial ol is largely altered.
Thin section is from the end of a minicore. Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-74R-6 (Piece 4A, 41-43 cm)**

**ROCK NAME:** Microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Granular to oikocrystic

**GRAIN SIZE:** Fine

**OBSERVER:** BLM/MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 57.0 | 57.0 | 0.2-2.0 | | Anhedral-euhedral | Chadacrysts. |
| Clinopyroxene | 23.5 | 24.7 | 0.1-0.6 | | Anhedral, granular | Oikocrysts up to 12 mm. |
| Oxide | 5.8 | 5.8 | 0.1-0.5 | | Euhedral-anhedral | Largely anhedral, intergrown with cpx and plag. |
| Orthopyroxene | 11.5 | 12.0 | | | | |
| Apatite | 0.5 | 0.5 | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | Along fractures. |
| Actinolite | 1.2 | Cpx | Rimming some cpx. |
| Tremolite | 0.5 | Opx | Small clots after cpx. |

**COMMENTS:** Fresh. Opaque-bearing microgabbro has a largely granular texture with occasional large oikocrysts containing both plag and opaque chadacrysts. The oikocrysts are opx while the smaller discrete grains are cpx. Percentages based on 1000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-74R-6 (Piece 5B, 115-119 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subhedral granular

**GRAIN SIZE:** Coarse to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8 | 10 | 0.5-2.0 | | Anhedral | Intergranular, grown around plag. |
| Plagioclase | 55 | 60 | 0.5-5.0 | | Anhedral | Some adcumulus growth. |
| Clinopyroxene | 28 | 30 | 0.1-4.0 | | Anhedral | Intergranular, rarely as oikocrysts enclosing only plag. |
| Oxide | Tr | | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | | Fractures in cpx and plag. |
| Chlorite | 1 | | Veins through plag, with oxides sometimes. |
| Actinolite | 5 | Cpx | On rims, also in veins through rock. |
| Opaques | 0.5 | Ol | On fractures, with clays. |
| Talc/Tremolite | 1.5 | Ol | |

**COMMENTS:** A small proportion of the cpx have the clear, blebby cpx or amphibole intergrowths common in the last few cores. Moderately dense fracture network through the sample; actinolite/chlorite/clay(?) in the fractures.

## THIN SECTION DESCRIPTION

**118-735B-75R-5 (Piece 1A, 27-30 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2.2 | 3 | 0.4-2.0 | | Anhedral | Intergranular. |
| Plagioclase | 57.7 | 58 | 0.4-6.0 | | Subhedral-anhedral | In large aggregates. |
| Clinopyroxene | 37.2 | 39 | 0.3-8.0 | | | Intergranular to poikilitic. |
| Spinel | 0.1 | 0.1 | 0.1-0.2 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 0.9 | Cpx | |
| Opaque | 0.9 | Ol | <0.05 mm grains along fractures, with clays(?) |
| Amphibole | 1.0 | Cpx | Colorless, patchy replacement of cpx. |

**COMMENTS:** Only plag is included in cpx, not ol.
Percentages based on 1200 point counts.

## THIN SECTION DESCRIPTION

**118-735B-75R-6 (Piece 3, 75-77 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 14 | | | | | Kinked. |
| Plagioclase | 60 | | | | | |
| Clinopyroxene | 23 | | | | | Intergranular-subophitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Plag | |
| Clays | Tr | Ol | Fractures in ol. |
| Actinolite | 2.5 | Cpx | |
| Oxide | 0.5 | Ol | In fractures. |

**COMMENTS:** Fresh gabbro; slight alteration, no deformation.

## THIN SECTION DESCRIPTION

**118-735B-76R-3 (Piece 2C, 50-52 cm)**

**ROCK NAME:** Gabbronorite

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Coarse to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 45 | | | | | Granular. |
| Clinopyroxene | 29 | | | | | Granular. |
| Fe-Ti oxide | 2 | | | | | |
| Orthopyroxene | 8 | | | | | Oikocrysts. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Actinolite | 8 | |
| Hornblende | 8 | |

**COMMENTS:** Coarse to medium gabbronorite with opx oikocrysts in both medium and coarse-grained parts. Grain boundary contact is rather sharp. A zone of extensive amphibolitization cuts across one side of the slide.

## THIN SECTION DESCRIPTION

**118-735B-76R-3 (Piece 2H, 93-97 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 8.0 | 10 | 2.0-5.0 | | Anhedral | |
| Plagioclase | 64.0 | 64 | 5.0-10.0 | | Subhedral | |
| Clinopyroxene | 25.2 | 26 | 2.0-5.0 | | Anhedral | Exhibits ophitic to subophitic texture, some oikocrystic. |
| Ilmenite | 0.1 | | 0.1 | | Anhedral | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | |
| Chlorite | 0.1 | | Interstitial, replacing plag in fractures. |
| Talc | 0.6 | Ol | |
| Magnetite | 1.1 | Ol | |
| Brown amphibole | Tr | Cpx | Brown. |
| Green amphibole | 0.8 | Cpx | Green. Fills thin veins, replaces or rims ol, alteration halos |

**COMMENTS:** Percentages based on 1500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-76R-4 (Piece 1I, 86-90 cm)**

**ROCK NAME:** Fe-Ti oxide gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** PTR

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 30 | 55 | 0.1-9.0 | | Subhedral-Anhedral | Recrystallized in shear zone |
| Clinopyroxene | 20 | 44 | 0.1-9.0 | | Euhedral-Anhedral | Replaced extensively by amphibole. |
| Fe-Ti oxide | 1 | 1 | 0.5-3 | | | Concentrated in shear zone |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | Tr | Plag | |
| Epidote | 1 | plag | |
| Actinolite | 10 | CPX | Colorless prismatic grains. |
| Hornblende | 14 | CPX | Brown and green varities. |
| Plagioclase | 20 | Plag | Neoblasts in shear zone. |
| Fe-Ti oxide | 4 | Pl/CPX | In shear zone. |

**COMMENTS:** A coarse-grained porphyroclastic gabbro composed of plag, cpx and minor oxides cut by a shear zone in which plag and cpx have been granulated and replaced, plag is replaced by small neoblasts and cpx by actinolite and hbd. Irregular grains of Fe-Ti oxide are concentrated in the shear zone.

## THIN SECTION DESCRIPTION

**118-735B-76R-5 (Piece 1F, 62-64 cm)**

**ROCK NAME:** Olivine gabbro cut by a "vein"

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 15 | 1-5 | | Rounded | |
| Plagioclase | 54 | 65 | 2-8 | | Euhedral | |
| Clinopyroxene | 16 | 18 | 2-8 | | Anhedral | |
| Orthopyroxene | 1 | 2 | | | Anhedral | Late interstitial. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Carbonate | Tr | Vein, plag | |
| Chlorite | 2 | Vein | Dark spherulitic mass. |
| Albite | 7 | Plag, vein | Colorless rims and blocks. |
| Epidote | 1 | Plag, vein | Clinozoisite. |
| Actinolite | 1 | Cpx, vein, cpx | Colorless, radial. |
| Sphene | <1 | Vein | Pink, euhedral. |
| Hornblende | 3 | Cpx/vein | Brown to green. |
| Talc | 4 | Ol | Mixed with magnetite. |
| Magnetite | 1 | Ol | Mixed with talc. |
| Hematite | Tr | Ol | Red stain. |

**COMMENTS:** The vein appears to be an intense in situ replacement of plag and cpx to a fine-grained mesh of secondary minerals. Could involve some cataclasis.

## THIN SECTION DESCRIPTION

**118-735B-77R-1 (Piece 2C, 33-35 cm)**

**ROCK NAME:** Olivine gabbro cut by white vein

**WHERE SAMPLED:**

**TEXTURE:** Orthocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | | 1.0-2.0 | | | |
| Plagioclase | 25 | | 1.0-4.0 | | | Symplectites with 2% cpx and brown hbd near vein |
| Clinopyroxene | 10 | | 1.0-4.0 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Vein | Brown, spherulitic, adjacent to carbonate. |
| Carbonate | 5 | Vein | Large crystals, could replace px or epidote. |
| Albite | 22 | Vein/plag | Spongy masses and veins. |
| Epidote | 1 | Vein | Zoned clinozoisite. |
| Actinolite | 13 | | Colorless spherules replacing cpx and ol cores near vein. |
| Hornblende | 10 | Vein | Small euhedral grains. |
| Prehnite | 1 | Ol cores | Near vein. |
| Talc | <1 | Ol | |

**COMMENTS:** Above primary mineralogy is for vein only; inadequate gabbro in section to describe or estimate primary modal abundance.

## THIN SECTION DESCRIPTION

**118-735B-78R-1 (Piece 5B, 132-136 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 9.5 | 11 | | | |
| Plagioclase | 51.5 | 52 | | | |
| Clinopyroxene | 35.0 | 37 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.8 | Ol | |
| Chlorite | 0.6 | Plag | In thin fractures. |
| Talc | 0.2 | Ol | |
| Magnetite | 0.6 | Ol | |
| Brown amphibole | 1.5 | Cpx | |
| Green amphibole | 0.2 | Cpx | Actinolite. |
| Colorless amphibole | 0.1 | Ol | Tremolite. |

**COMMENTS:** Slide contains contact between two different textures. In one half the cpx is extensively subophitic (oikocrystic), in the other half the cpx is more equant in shape, although still partially enclosing plag. Where the cpx is blocky in shape, it exhibits complex intergrowth relationships between adjacent crystals. Percentages based on 1000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-78R-4 (Piece 5B, 54-59 cm)**

**ROCK NAME:** Amphibolitized gabbro

**WHERE SAMPLED:**

**TEXTURE:** Subnedral granular

**GRAIN SIZE:** Coarse

**OBSERVER:** STA 317

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | 2 | 71 | | | Three grains; looks late |
| Plagioclase | 50 | 60 | 1-5 | | Tabular | Many now have sodic rims and inclusions. |
| Clinopyroxene | 10 | 35 | 2-5 | | | |
| Spinel | 2 | 3 | 61 | | | Ti-magnetite or ilmenite replaced by sphene |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Sodic plagioclase | 5 | Plag | Rims on plag and patchy alteration. |
| Epidote | Tr | Plag | Two small euhedral grains. |
| Hornblende | 15 | Cpx | Dark green, well crystallized after cpx, tabular to plumose. |
| Plagioclase | 5 | | Noeblasts in mosaic. Turbid with amphibole inclusions. |
| Mica | 2 | | Core of cpx grains; also constitutes the rim of alteration coronas with anthophylite + green mica. Very rad pleochroic. Phlogopite? |
| Sphene | 1 | spinel | Large grains in one corner of slide. |
| Hornblende | 5 | Qx | Brown, intertitial and blebs in cpx. |
| Amphibole | 5 | ?px or hb | Fe-Mg; fibrous; colorless to pale brown, rimmed by phlogopite. |
| Talc | Tr | ol | |

**COMMENTS:** Very altered gabbro. No primary ol remaining. Slight plastic deformation is shown by bent plag crystals and mosaic intergrowths.

## THIN SECTION DESCRIPTION

**118-735B-78R-4 (Piece 6, 65-67 cm)**

**ROCK NAME:** Porphyroclastic olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** fine-medium

**OBSERVER:** 318

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 3 | 5 | 1 | | | Porphyroclasts, to ≤4 mm. |
| Plagioclase | 60 | 80 | 1-10 | | | Porphyroclasts, to ≤4 mm. |
| Clinopyroxene | 10 | 15 | 1-4 | | | Porphyroclasts. |
| Orthopyrocene | Tr | Tr | | | | Exsolution cpx. |
| Brown amphibole | Tr | Tr | | | | Magmatic? |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 1 | Cpx, plag | |
| Plagioclase | 19 | Plag | Neoblasts ≤0.2 mm. |
| Clinopyroxene | 5 | Cpx | Neoblasts ≤0.2 mm. |
| Olivine | 2 | Ol | Neoblasts ≤0.2 mm. |

**COMMENTS:** Oriented thin section, cut from the end of a minicore. Fresh porphyroclastic gabbro. Very elongate and undulose ol and plag clasts. Rare in that the matrix is half granulated cpx + ol. Largely recrystallized. Plag still common as porphyroclasts. Some cpx clasts have clear, wormy intergrowth like those in some of the igneous cpx.

## THIN SECTION DESCRIPTION

**118-735B-79R-6 (Piece 3, 90-95 cm)**

**ROCK NAME:** Toctolite/olivine gabbro

**WHERE SAMPLED:** At contact between troctolite and olivine gabbro

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 28.0 | | 2.0-6.0 | | Anhedral |
| Plagioclase | 68.0 | | 3.0-10.0 | | Subhedral |
| Clinopyroxene | 3.0 | | 1.0-4.0 | | Anhedral |
| Ilmenite | Tr | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.2 | Ol | |
| Magnetite | 0.2 | Ol | |
| Brown amphibole | 0.6 | Cpx | Replaces cpx and surrounds ol and cpx in grain boundaries. |

**COMMENTS:** Mode is determined for troctolite-side of thin section. The other part of the slide is composed almost entirely of one green subophitic cpx; cpx approximately 2.5 cm long. Percentages based on 1500 point counts.

## THIN SECTION DESCRIPTION

**118-735B-79R-7 (Piece 9, 99-102 cm)**

**ROCK NAME:** Troctolitic microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Equigranular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** MEY

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 19.8 | 19.8 | 0.3-1.0 | | Subhedral-euhedral | Sometimes enclosed in cpx. |
| Plagioclase | 72.6 | 72.6 | 0.5-1.5 | An 65 | Subhedral-euhedral | Exhibits concentric normal zoning.<br>Oikocrysts enclose ol and plag. |
| Clinopyroxene | 5.7 | 5.7 | 0.5-2.0 | | | |
| Opaque | 0.2 | 0.2 | <0.1 | | | |
| Hornblende | 1.7 | 1.7 | <0.1 | | | Rims around cpx. |
| Sulphide | Tr | Tr | <0.1 | | Subhedral | Partially enclosed in ol. |

**COMMENTS:** Fresh, undeformed. Hbd and opaque phases are primary and represent late stage crystallization products of intercumulus liquid. Percentages based on 1170 point counts. Plag composition determined by Michel-Levy method.

## THIN SECTION DESCRIPTION

**118-735B-80R-2 (Piece 4, 35-40 cm)**

**ROCK NAME:** Troctolitic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY |
|---|---|---|---|---|---|
| Olivine | 19.7 | 19.8 | 0.2-0.3 | | Anhedral |
| Plagioclase | 64.1 | 64.1 | 1.0-2.0 | | Anhedral |
| Clinopyroxene | 15.8 | 16.1 | 0.2-1.0 | | Anhedral |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | |
| Brown amphibole | 0.3 | Cpx | Replaces cpx and occurs surrounding cpx, ol and ilmenite. |

**COMMENTS:** Cpx generally occurs wrapped around ol. Brown amphibole then either rims cpx or partially replaces it.

## THIN SECTION DESCRIPTION

**118-735B-80R-6 (Piece 1, 6-9 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 11.5 | 12 | 1.0-4.0 | | Anhedral | |
| Plagioclase | 50.5 | 51 | 3.0-10.0 | | Subhedral | |
| Clinopyroxene | 35.3 | 37 | 3.0-10.0 | | Anhedral | |
| Orthopyroxene | 0.1 | | | | Anhedral | Exsolution from cpx. |
| Ilmenite | Tr | | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.5 | Ol | |
| Magnetite | 0.3 | | |
| Brown amphibole | 1.8 | Cpx | Replaces cpx in patches and lines grain boundaries between cpx and plag and ol and plag. |

**COMMENTS:** Brown amphibole invades cpx in a pervasive manner creating a symplectite-like texture. Adjacent grains of cpx often have very complex grain boundary relationships in which two crystals are intergrown. Percentages based on 1000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-80R-7 (Piece 1C, 23-25 cm)**

**ROCK NAME:** Ilmenite-olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Fine to medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9 | 10 | 0.1-0.3 | | Anhedral | |
| Plagioclase | 35 | 35 | 0.1-2.0 | | Anhedral | |
| Clinopyroxene | 32 | 40 | 0.2-2.0 | | Anhedral | |
| Opaques | 15 | 15 | 0.05-0.6 | | Anhedral | |
| Orthopyroxene | Tr | | | | | Exsolution form cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | |
| Green amphibole | 7 | Amphibole, plag | Some blue-green amphibole replacing brown amphibole, cpx, and some plag along fractures. |
| Brown amphibole | 1 | Cpx | Surrounding oxides and replacing cpx. |

**COMMENTS:** Very faintly foliated.

## THIN SECTION DESCRIPTION

**118-735B-81R-2 (Piece 2B, 54-56 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Hypidiomorphic granular

**GRAIN SIZE:** Coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 12 | 12 | 1.0-3.0 | | Anhedral | |
| Plagioclase | 50 | 50 | 1.0-10.0 | | Subhedral-euhedral | |
| Clinopyroxene | 37 | 38 | 1.0-9.0 | | Anhedral | Subophitically to ophitically encloses plag. |
| Opaques | Tr | Tr | | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Opaques | Tr | Ol | Replacing ol along fractures. |
| Brown amphibole | 1 | Cpx | Patchy replacement of cpx and as thin film on grain boundaries. |
| Green amphibole | Tr | Vein | |

## THIN SECTION DESCRIPTION

**118-735B-81R-5 (Piece 1, 1-7 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Subophitic Opaques
**GRAIN SIZE:** Medium
**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7.4 | 8 | 1-2 | | Anhedral | Rimmed by filmy opx, cpx, or amphibole. |
| Plagioclase | 59.5 | 61 | 2-4 | | Subhedral-anhedral | |
| Clinopyroxene | 16 5 | 31 | 1-3 | | Anhedral | Subophitic. Complex intergrowth with opx and brown hbd (exsolution?) is common. |
| Spinel | Tr | Tr | 0.1-0.5 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 0.1 | Ol | Filling in fractures. |
| Chlorite | Tr | Ol | |
| Albite | 0.5 | Plag | Along fractures on one side of the thin section. |
| Actinolite | 0.3 | Cpx | |
| Hornblende | 0.2 | Cpx | Brown amphibole after cpx. Possibly primary. |
| Talc/tremolite | 0.5 | Ol | Occurs with opaques. |
| Amphibole | 15.0 | Cpx | Clear blebby patches after cpx. Possibly some kind of a primary intergrowth. |

**COMMENTS:** Percentages based on 2000 point counts.

## THIN SECTION DESCRIPTION

**118-735B-81R-7 (Piece 6A, 64-66 cm)**

**ROCK NAME:** Olivine gabbro
**WHERE SAMPLED:**
**TEXTURE:** Allotriomorphic granular
**GRAIN SIZE:** Medium to coarse
**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 9 | 10 | 0.5-2.0 | | Anhedral | Altered to clay + opaques in fractures. |
| Plagioclase | 50 | 55 | 0.5-5.0 | | Anhedral | |
| Clinopyroxene | 27 | 35 | 0.8-4.0 | | Anhedral | |
| Orthopyroxene | Tr | Tr | 0.1-0.2 | | Anhedral | Exsolution from cpx, also rimming ol and cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | Ol | Olive-green. |
| Plagioclase | 5 | Plag | Neoblasts. |
| Amphibole | 3 | Cpx | Patchy replacement of cpx and along grain boundaries. |
| Clinopyroxene | 5 | Cpx | Neoblasts. |

**COMMENTS:** Weakly foliated. Some granulation along plag grain boundaries.
Contains complex replacement/recrystallization textures of cpx involving brown amphibole.
Ol often enclosed in cpx, or occuring with a thin layer of cpx around it.

## THIN SECTION DESCRIPTION

**118-735B-82R-1 (Piece 3, 49-54 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Medium to coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 27 | 31 | 1-2 | | Anhedral | |
| Plagioclase | 46 | 51 | 1-3 | | Tabular | |
| Clinopyroxene | 15 | < 17 | 2-5 | | | Poikilitic oikocrysts. |
| Magnetite | < 1 | < 1 | | | Euhedral | |
| Hornblende | 1 | 1 | | | | Interstitial. Brown. Blebs in cpx. Surrounds ilmenite and cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Serpentine | 1 | Ol | Along cracks. |
| Actinolite | 1 | Ol | |
| Hornblende | 2 | Vein | In vein. |
| Plagioclase | 3 | Plag | In vein. Euhedral crystals. |
| Clinopyroxene | 2 | Vein | Green. In hydrothermal vein and in symplectites. |
| Talc | 1 | Ol | Occurs with magnetite in pseudomorphs. |
| Magnetite | < 1 | Ol | |
| Mica(?) | < 1 | Plag | Fibrous aggregates. |

**COMMENTS:** According to the core description, this sample is at the boundary between green and brown cpx. Large cpx in coarse half of thin section are slightly altered to amphibole and contain large regions of "exsolved" px symplectites, cut by interstitial vein of euhedral plag+ green cpx(?) + brown hbd. Vein also cuts ol. Same mineralogy occurs as clots in other parts of the section.

## THIN SECTION DESCRIPTION

**118-735B-82R-2 (Piece 1B, 13-15 cm)**

**ROCK NAME:** Troctolitic microgabbro

**WHERE SAMPLED:**

**TEXTURE:** Allotriomorphic granular

**GRAIN SIZE:** Medium

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 15 | 15 | 0.4-2.5 | | Anhedral | |
| Plagioclase | 70 | 70 | 0.5-4.0 | | Anhedral | |
| Clinopyroxene | 14 | 15 | 0.5-8.0 | | Anhedral | Very skeletal, oikocrystic texture. Oikocrysts up to 8 mm in size. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Opaques | Tr | Ol | |
| Amphibole | 1 | Cpx | Brown. Patchy replacement of cpx and along grain boundaries. |

## THIN SECTION DESCRIPTION

**118-735B-82R-4 (Piece 4A, 41-46 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mesocumulate

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 14 | 15 | 0.5-1.0 | | Anhedral | |
| Plagioclase | 50 | 50 | 1-3 | | Subhedral | |
| Clinopyroxene | 35 | 35 | 2-6 | | | Poikilitic. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Tremolite | < 1 | Ol | Possibly an orthoamphibole. |
| Talc | < 1 | Ol | |

**COMMENTS:** Much of the slide has been plucked or polished off.

## THIN SECTION DESCRIPTION

**118-735B-82R-6 (Piece 2, 11-13 cm)**

**ROCK NAME:** Ilmenite-orthopyroxene-bearing gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Variable, fine to medium (<1-5 mm)

**OBSERVER:** HEB

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 5 | 40 | <0.5 | | Anhedral | Included in cpx or recrystallized as neoblasts. |
| Clinopyroxene | 44 | 48 | ≈1-4 | | Euhedral | Large crystals which contain inclusions of brown amphibole, euhedral ilmenite, small exsolution lamellae of opx(?). |
| Ilmenite | 3 | 6 | 0.1 | | Anhedral | Large grains with magmatic contact with cpx. |
| Orthopyroxene | 3 | 6 | 2-3 | | Anhedral | Recrystallized, intergrowth, or wrapped by ilmenite/magnetite. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 3 | Opx, cpx | Green, mantling the brown amphibole and cpx. |
| Plagioclase | 35 | Plag | Neoblasts, <0.5 mm. Mosaic of equilibrated polygonal grains. |
| Amphibole | 4 | Cpx | Brown. Patches in cpx or at outer margins of grains. |
| Magnetite | 3 | Ilmenite | Small granules associated with ilmenite in the intergranular spaces surrounding cpx. |

**COMMENTS:** Partially remobilized ilmenite.
High temperature type of remobilization without important fluid phase: cpx + opx are almost fresh.
Deformation plays an important role here.

## THIN SECTION DESCRIPTION

**118-735B-83R-4 (Piece 5A, 95-97 cm)**

**ROCK NAME:** Porphyroclastic metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** KEM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10 | 15 | | | Anhedral | Altered to clay and opaques on fractures. |
| Plagioclase | 15 | 50 | | | Euhedral–anhedral | |
| Clinopyroxene | 22 | 35 | | | Anhedral | Augen ophitically encloses euhedral plag. |
| Orthopyroxene | 1 | 0 | | | | Blebby exsolution from cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | Replacing ol along fractures. |
| Plagioclase | 35 | Plag | Neoblasts. |
| Clinopyroxene | 10 | Cpx | Neoblasts. |
| Brown amphibole | 2 | Cpx | Interstitial between cpx neoblasts. |
| Olivine | 5 | Ol | Neoblasts. |
| Opaques | Tr | Ol | |

## THIN SECTION DESCRIPTION

**118-735B-83R-7 (Piece 4D, 77-81 cm)**

**ROCK NAME:** Troctolite

**WHERE SAMPLED:**

**TEXTURE:** Sub-poikilitic

**GRAIN SIZE:** Fine to coarse, 1-2 mm average

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 50 | 55 | 0.5-2.0 | | Subhedral—anhedral | Enclosed in plag and cpx. |
| Plagioclase | 20 | 38 | 0.2-10.0 | | Intergranular—ophitic | Occasionally enclosed in ol. |
| Clinopyroxene | 3 | 4 | 10.0-20.0 | | Interstitial | Large discontinuous oikocrysts. |
| Spinel | 3 | 3 | 0.1-0.3 | | Euhedral—subhedral | Enclosed in ol, plag and cpx. Often has round inclusions of ol or plag up to half the diameter of the grain. Rust-red, slightly translucent in plain light. Commonly accompanied by amphibole. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 6 | Plag | Clots and books of white-grey, with anomalous parallel extinction. |
| Actinolite | 1 | Plag | Fibrous mats in altered plag. |
| Talc | 8 | Ol | |
| Tremolite | 8 | Ol, plag | |
| Magnetite | 1 | Ol | |
| Cummingtonite? | <1 | Ol, plag | High relief, fibrous, moderately high birefringence. |
| Hornblende | <1 | Ol, spinel | Clear, yellow to pale orange-brown rimming spinel. |

**COMMENTS:** Weakly deformed, plag shows undulose extinction and the formation of some subgrain boundaries and neoblasts. Ol has numerous kink bands bands and is frequently elongated and stretched to form a weak foliation. Spinel is often rimmed with an orange-brown amphibole indicating either late deuteric or other metamorphic reaction with a fluid.

## THIN SECTION DESCRIPTION

**118-735B-83R-7 (Piece 6, 104-106 cm)**

**ROCK NAME:** Troctolite

**WHERE SAMPLED:**

**TEXTURE:** Poikilitic

**GRAIN SIZE:** 0.5-2.0 mm

**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 40 | 55 | 0.5-1.0 | | Euhedral-anhedral | Some have plag inclusions. |
| Plagioclase | 20 | 44 | 0.5-3.0 | | Subophitic-ophitic | |
| Sulphides | Tr | Tr | 0.1 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING |
|---|---|---|
| Actinolite | 5 | Plag |
| Tremolite | 20 | Ol, plag |
| Brown amphibole | Tr | |
| Talc | 5 | Ol |
| Albite | 10 | Plag |

**COMMENTS:** Ol grains rimmed by tremolite, actinolite and talc replacing and enclosing plag and a portion of the ol.

## THIN SECTION DESCRIPTION

**118-735B-84R-3 (Piece 1B, 14-16 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:** Anhedral granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 7 | 10 | 0.5-1.5 | | Anhedral | Partially enclosing plag. |
| Plagioclase | 58 | 65 | 1.0-3.0 | | Anhedral | |
| Clinopyroxene | 19 | 25 | 0.5-2.0 | | Anhedral | Intergranular. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 1 | | On fractures in cpx and ol. |
| Actinolite | 2 | Cpx, ol | Thin greenish rims on ol, a little on cpx? Fibrous aggregates in shear zone. |
| Hornblende | 1 | Cpx | Brown rims on some cpx. |
| Plagioclase | 5 | Plag | <0.2 mm neoblasts; largely on grain margins. |
| Talc/tremolite | 2 | Ol | |
| Opaques | 1 | Ol | Occurs with talc/tremolite. |
| Amphibole | 4 | Cpx | Clear patches, sometimes with small exsolution-like features. |

**COMMENTS:** Moderate deformation. Most plag-plag contacts are lined with a mosaic of 0.1-0.2 mm recrystallized plag. Larger grains are undulose; ol is kinked. A 0.6 mm-wide vein of mosaic plag and actinolite cuts one side of sample; this was probably a shear zone that was subsequently altered.

## THIN SECTION DESCRIPTION

**118-735B-84R-5 (Piece 9, 80-82 cm)**

**ROCK NAME:** Olivine gabbro

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Fine to medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 10.4 | 12 | 1.0-4.0 | | Anhedral | Intergranular. |
| Plagioclase | 51.0 | 52 | 1.0-6.0 | | Anhedral | |
| Clinopyroxene | 30.0 | 36.8 | 2.0-4.0 | | Anhedral | Subophitic. |
| Oxide | 0.4 | 0.4 | <1.5 | | Anhedral | |
| Amphibole | 0.8 | 0.8 | | | | Brown. Occurs as patches in cpx. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 1.4 | Cpx | A small amount in veins. |
| Talc/Tremolite | 1.5 | Ol | |
| Oxide | 0.3 | Ol | |
| Clear amphibole | 4.2 | Cpx | Clear, blebby intergrowths with cpx. |

**COMMENTS:** Percentages based on 1400 point counts.

## THIN SECTION DESCRIPTION

**118-735B-85R-4 (Piece 1B, 9-11 cm)**

**ROCK NAME:** Foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Gneissic

**GRAIN SIZE:** Medium

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | 10 | 63 | 0.2-2.0 | | | Porphyroclasts. |
| Clinopyroxene | 10 | 35 | 1.0-3.0 | | | Porphyroclasts. |
| Ilmenite | 2 | 2 | <0.1 | | | Inclusions in cpx and mixed with neoblasts. |
| Hornblende | | 1? | <0.1 | | | Red-brown; pre-deformational and syndeformational. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Hornblende | 15 | Cpx | Green aggregates; post-deformational; also one late vein. |
| Plagioclase | 53 | | Neoblasts in mosaic texture. |
| Clinopyroxene | 10 | | Neoblasts in layers and tails on tips of cpx augen. |
| Rutile? | Tr | Ilmenite | Highly birefringent rods in hbd pseudomorph. |

**COMMENTS:** One late hbd vein is perpendicular to foliation. Optically similar hbd is observed on edge of recrystallized cpx porphyroclast oblique to foliation.

## THIN SECTION DESCRIPTION

**118-735B-85R-7 (Piece 1B, 17-19 cm)**

**ROCK NAME:** Troctolite

**WHERE SAMPLED:**

**TEXTURE:** Granular

**GRAIN SIZE:** Medium

**OBSERVER:** BLM

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 16.0 | 25.5 | 1.0-2.0 | | Anhedral | |
| Plagioclase | 65.0 | 65.0 | 1.0-2.0 | | Anhedral | |
| Clinopyroxene | 3.9 | 7.0 | 1.0-2.0 | | Anhedral | Rims on ol, interstitial grains. |
| Spinel | Tr | Tr | | | | |
| Orthopyroxene | 1.3 | 1.3 | <1.0 | | | Rims on ol. |
| Brown amphibole | 1.2 | 1.2 | <1.0 | | | Rims on ol. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1.6 | Ol | |
| Actinolite | 6.4 | Ol | Green in veins, rest clear as rims on ol and after cpx. |
| Talc/Tremolite | 4.6 | Ol | With fine opaques. |

## THIN SECTION DESCRIPTION

**118-735B-85R-7 (Piece 5, 79-85 cm)**

**ROCK NAME:** Poorly foliated metagabbro

**WHERE SAMPLED:**

**TEXTURE:** Cataclastic

**GRAIN SIZE:** Coarse

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 2 | 5 | 0.5-3.0 | | | Recrystallized and flattened. |
| Plagioclase | 49 | 55 | 2.0-4.0 | | | Recrystallized (partially). |
| Clinopyroxene | 30 | 40 | 1.0-4.0 | | | Partially recrystallized. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Chlorite | 1 | Plag | Radial; also lenses with tremolite. |
| Tremolite | 1 | Ol | Also ol-plag boundaries in corona structure. |
| Hornblende | | | Green-brown; in recrystallized zones in plag. Also euhedral grains along crack. |
| Plagioclase | 5 | Plag | Neoblasts. |
| Talc | 2 | Ol | Occurs with tremolite. |
| Hornblende | 1 | | Red-brown; syndeformational. |
| Clinopyroxene | 9 | Cpx | Neoblasts. |

**COMMENTS:** Texture is developed by crushed grains or recrystallized along grain boundaries and recrystallization within px and plag grains. Plag is kinked.

## THIN SECTION DESCRIPTION

**118-735B-86R-6 (Piece 19, 143-145 cm)**

**ROCK NAME:** Augen gneissic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Porphyroclastic

**GRAIN SIZE:** Fine to coarse

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | Tr | 2 | 0.3 | | | Kinked, marginally recrystallized, altered. |
| Plagioclase | 10 | 80 | < 10 | | | Recrystallized. |
| Clinopyroxene | 8 | 12 | < 10 | | | Marginally recrystallized. |
| Fe-Ti oxides | 2 | 2(?) | 0.1–4.0 | Fe-Ti | Subhedral | Large subhedral grains and anhedral smaller grains in tails of cpx. |
| Orthopyroxene | 2 | 5(?) | 1–4 | | Subhedral | Elongated fragments of original bigger grains, marginally recrystallized. |
| Hornblende | — | (?) | (?) | | | Brown. Recrystallized. Either partially or entirely secondary. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | Tr | Ol | |
| Opaques | Tr | Ol, opx | |
| Chlorite | Tr | Plag | |
| Actinolite | < 1 | Plag, ol, opx | Static. |
| Talc/tremolite | < 1 | Ol, opx | Static. |
| Hornblende | 2 | Cpx, hbd | Replacing primary brown hbd? Brown. Euhedral crystals, 0.1 mm. |
| Plagioclase | 70 | Plag | 0.05–0.20 mm in size. |
| Orthopyroxene | < 1 | Opx | 0.05–0.10 mm in size. |
| Clinopyroxene | 2 | Cpx | |
| Olivine | Tr | Ol | 0.1–0.2 mm in size. |
| Amphibole | 3 | Px | Greenish brown. Static. |

**COMMENTS:** Intense high temperature plastic deformation. Late static replacement by hydrous phases.

## THIN SECTION DESCRIPTION

**118-735B-87R-7 (Piece 1C, 15-17 cm)**

**ROCK NAME:** Hydrothermal vein

**WHERE SAMPLED:**

**TEXTURE:**

**GRAIN SIZE:** Medium to fine

**OBSERVER:** STA

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPOSITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 50(?) | | | | Cracked and albitized. |
| Clinopyroxene | 7 | 10(?) | | | | Amphibolitized relict. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Clays | 3 | Chlorite | Fe-stained, on edge of chlorite masses. Iddingsite, on cracks and edge of chlorite. |
| Carbonate | 10 | Vein(?), plag, cpx | Replaces plag. |
| Chlorite | 40 | Vein, plag | Spherulitic bundles, partially oxidized in vein. Also replacing plag. |
| Epidote | Tr | Chlorite, carbonate | Angular grains in chlorite and carbonate. |
| Sphene | 1 | | Large euhedral grain. |
| Plagioclase + albite | 35 | Vein | Lantern-shaped to anhedral. |
| Hematite | 2 | | |

**COMMENTS:** In one part of the slide, calcite and chlorite have a scalloped, concave margin. This suggests that the calcite is replacing calcic plag subsequent to its partial replacement by chlorite. Euhedral cpx is intergrown with calcite (possibly replacing a symplectite). Calcite is also the groundmass for numerous small euhedral grains of albite (or sodic plag) and cpx. Too much of the texture is destroyed to determine whether all of the calcite is late.

## THIN SECTION DESCRIPTION

**118-735B-87R-5 (Piece 3, 20-22 cm)**

**ROCK NAME:** Amphibolitized mylonitic gabbro

**WHERE SAMPLED:**

**TEXTURE:** Mylonitic

**GRAIN SIZE:** Fine with augens

**OBSERVER:** CAN

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Plagioclase | — | 55 | | | | Completely recrystallized. |
| Clinopyroxene | 20 | 40 | | | Augite | Some cpx is recrystallized. |
| Hornblende | (?) | (?) | | | | Brown. All of the brown hbd is included in the secondary mineralogy percentages, but may be primary. |
| Fe-Ti oxides | 4 | (?) | <0.01–0.04 | Fe-Ti | | Aggregates or disseminated. All of the Fe-Ti oxides are included in the primary mineralogy percentages, but some crystals are obviously remobilized during deformation. |
| Orthopyroxene | 1 | (?) | 0.1–0.4 | | | Augens. Probably (but not absolutely certainly) recrystallized. |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Actinolite | 15 | Plag | Very green. Static replacement of large areas of plag. |
| Hornblende | 15 | Cpx, veins | Brown to dark green. Locally dynamic, but mostly static replacement of cpx. Hbd in veins is not deformed. |
| Plagioclase | 40 | Plag | Recrystallized grains, 0.1 mm in size. |
| Clinopyroxene | 5 | Cpx | Recrystallizied grains, 0.1 mm in size. |

**COMMENTS:** Thin section is from the end of a minicore. A first plastic event produced the plag and cpx recrystallization, and the foliation. The amphiboles seem mostly undeformed, however there is some brownish amphibole in the tails of rotated cpx augens in discrete mylonitic shears (grain size 20 μm). The Fe-Ti oxides are distinctly distributed (stretched or crystallized?) along these shears. The amphibole veins are not deformed but locally appear as filling gaps in the plag between two discrete shears.

## THIN SECTION DESCRIPTION

**118-735B-87R-7 (Piece 6, 51-56 cm)**

**ROCK NAME:** Troctolite

**WHERE SAMPLED:**

**TEXTURE:** Poikilitic

**GRAIN SIZE:** Fine to coarse

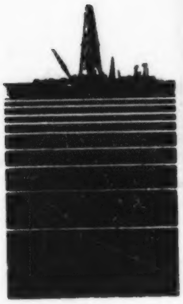
**OBSERVER:** DCK

| PRIMARY MINERALOGY | PERCENT PRESENT | PERCENT ORIGINAL | SIZE RANGE (mm) | APPROX. COMPO-SITION | MORPHOLOGY | COMMENTS |
|---|---|---|---|---|---|---|
| Olivine | 28 | 35 | 0.5–1.5 | | Subhedral–anhedral | |
| Plagioclase | 49 | 60 | 1–5 | | | Ophitic to poikilitic. |
| Clinopyroxene | 5 | 5 | 20 | | | Oikocryst. Discontinuous 2 cm mesh. |
| Sulfides | Tr | Tr | <0.1 | | | |

| SECONDARY MINERALOGY | PERCENT | REPLACING/ FILLING | COMMENTS |
|---|---|---|---|
| Albite | 1 | Plag | Locally rimming plag grain boundaries. |
| Tremolite | 15 | Plag, ol | Reaction coronas around ol, between ol and plag. |
| Magnetite | 1 | Plag, ol | Locally rimming ol where tremolite is absent. Pale pink pleochroism. Possibly interstitial deuteric amphibole. |
| Amphibole | 1 | Plag, ol | |

**COMMENTS:** Cpx oikocrysts are discontinuous but large, and enclose both ol and occasional euhedral plag laths. Late interstitial amphibole locally present, locally enclosing ol; possibly deuteric. Interstitial cpx coarsens to form discontinuous, large oikocrysts.

# SECTION 4: POLICY



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Miriam Kastner (Planning Committee liaison)
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Kim D. Klitgord (Atlantic Regional Panel liaison)
*U.S. Geological Survey*
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*Columbia University*
Marcia McNutt
*Massachusetts Institute of Technology*
John Malpas
*Memorial University*
Catherine Mevel
*Université Pierre et Marie Curie*
John C. Mutter
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John C. Mutter (Lithospheric Panel liaison)
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*Texas A&M University*
Junzo Kasahara
*Nippon Schlumberger K.K.*
Emilio Luna Sierra
*Hispanoil*
Archie R. McLerran
*Solana Beach, California*
Keith Manchester
*Atlantic Geoscience Centre (Canada)*
Claus Marx
*Institut für Tiefbohrkunde und Erdölgewinnung*
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# SAMPLE-DISTRIBUTION POLICY[1]

Distribution of Ocean Drilling Program (ODP) and Deep Sea Drilling Project (DSDP) samples is undertaken in order to (1) provide support to shipboard scientists in achieving the scientific objectives of their cruise and to support shore-based investigators who are preparing contributions to ODP reports, (2) provide individual investigators with materials to conduct detailed studies beyond the scope of ODP reports, (3) provide micropaleontological reference centers with samples for reference and comparison purposes, and (4) provide educators with samples for teaching purposes.

Funding for sample-related activities must be secured by the investigator independently of requesting the samples.

The Ocean Drilling Program Curator is responsible for distributing samples and for preserving and conserving core material. The Curator, who may accept advice from chairmen of the appropriate JOIDES advisory panels, is responsible for enforcing the provisions of this sample-distribution policy. He is responsible for maintaining a record of all samples that have been distributed, both on board ship and subsequently from the repositories, indicating the recipients and the nature of investigations proposed. This information is available to interested investigators on request.

Every sample distributed from the ship or from a repository is labeled with a standard identifier, which includes leg number, hole number, core and section numbers, and interval within the section from which the sample was removed. It is imperative that this standard identifier be associated with all data reported in the literature, and that residues of the sample remain labeled throughout their lives, so that later workers can relate the data to the cores.

Distribution of sample materials is made directly from the repositories (Lamont-Doherty Geological Observatory, Scripps Institution of Oceanography, and Texas A&M University) by the Curator or his designated representative.

1. *Distribution of Samples for Research Leading to Contributions to ODP Reports*

Any investigator who wishes to contribute to the reports of a scheduled cruise may write to the Curator, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A., in order to request samples from that cruise. Requests for a specific cruise must be received by the Curator at least TWO MONTHS in advance of the departure of that cruise, in order to allow time for review of the request in conjunction with other requests, so that a suitable shipboard sampling program can be assembled. The request should include a statement of the nature of the proposed research, the size and approximate number of samples required to complete the study, and any particular sampling technique or equipment which may be required. Requests will be reviewed by the Staff Representative and co-chief scientists of the cruise and by the Curator. Approval/disapproval will be based on the scientific requirements of the cruise as determined by the appropriate JOIDES advisory panel(s). The scope of a request must be such that samples can be processed, that proposed research can be completed, and that the paper can be written in time for submission to the relevant ODP cruise report.

Except for rare, specific instances involving ephemeral properties, the total volume of samples removed during a cruise-related sampling program will not exceed one-quarter of the volume of core recovered, and no interval will be depleted. One-half of all recovered materials will be retained in the archives in as pristine a condition as is practicable. Investigators requesting shipboard samples of igneous materials may receive a maximum of 100 igneous samples per cruise.

Because many sample requests are received for shipboard work and because the time of the shipboard party is at a premium, co-chief scientists are strongly urged to limit shipboard sampling to the minimum necessary to accomplish the cruise objectives. Shore-based investigators whose requests for cruise-related samples are approved should expect that they will receive the samples after the cores are returned to the repository, and should schedule research activities accordingly.

Co-chief scientists may invite investigators who are not cruise participants to perform special studies of selected core samples in direct support of shipboard activities. If this occurs, the names and addresses of these investigators and details of all samples loaned or distributed to them must be forwarded to the Curator, via the ODP Staff Representative to that cruise, immediately after the cruise. These investigators are expected to contribute to the cruise reports as though they had been cruise participants. All requirements of the Sample-Distribution Policy apply.

Any publication of results other than in ODP reports within twelve (12) months of completion of the cruise must be approved and authored by the whole shipboard party and, where appropriate, shore-based investigators. After twelve (12) months, individual investigators may submit related papers for open publication, provided they have already submitted their contributions to ODP reports and had them accepted. Investigations which are not completed in time for inclusion in the ODP reports for a specific cruise may be published in a later edition of the ODP reports; however, they may not appear in another journal until the report for which they were intended has been published.

2. *Distribution of Samples for Research Leading to Publication Outside of the ODP Reports*

A. Researchers who wish to use samples for studies beyond the scope of the ODP reports should obtain sample-request forms from the Curator, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A. Requestors are required to specify the quantities and intervals of core required, to make a clear statement of the nature of the proposed research, to state the time which will be required to complete the work and to submit results for publication, and to specify funding status and the availability of equipment and space for the research.

Additionally, if the requestor has received samples from ODP or from DSDP previously, he/she will be required to account for the disposition of those samples by citing published works, four (4) copies of which must be sent to the Curator. If no report has been published, this requirement can be fulfilled by sending a brief (two- or three-page) report of the status of the research.

If the requestor has never before received samples from ODP or DSDP, he/she will be required to show that the samples will be used for responsible research. This requirement can be met by providing the Curator with a copy of the requestor's résumé and bibliography. If the requestor is a student working on a higher degree, he/she can meet this requirement by sending a copy of his/her dissertation or research proposal endorsed by the student's advisor.

Unused and residual samples should be returned and data should be sent to the Curator if the project has terminated. Paleontological materials may be returned either to the Curator at ODP or to one of the designated micropaleontological reference centers. If material is returned to a reference center, notify the Curator when it is sent.

Requests for samples from researchers in industrial laboratories will be honored in the same manner as those from academic organizations. Industrial investigators have the same obligations as other investigators to publish all results promptly in the open literature and to provide the Curator with copies of all reports published and of all data acquired in their research.

In order to ensure that all requests for highly desirable but limited samples can be considered together, approval of requests and distribution of samples will be delayed until twelve (12) months after completion of the cruise or two (2) months after official publication of the core descriptions, whichever occurs earlier. The only exceptions to this policy will be made for specific requests involving ephemeral properties. Requests for samples may be based on core descriptions published in ODP reports produced by the shipboard party, copies of which are on file at various institutions throughout the world. Copies of original core logs and data are kept on open file at ODP, and at the repositories at Lamont-Doherty Geological Observatory and Scripps Institution of Oceanography.

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[1] Revised October 1988.

B. Most investigations can be accomplished handily with sample volumes of 10 mL or less. Investigators must provide explicit justification of requests for larger sample sizes or for frequent intervals within a core. Requests which exceed reasonable size or frequency limits will require more time to process and are unlikely to be granted in their entirety.

Requests for samples from thin layers, from stratigraphically important boundaries, or from sections which are badly depleted or in unusually high demand may be delayed in order to coordinate requests from several investigators or while the Curator seeks advice from the community. Investigators who submit such requests may expect to receive suggestions for alternative sampling programs or for joining with a research consortium which will share the samples. In any event, such exceptional requests will require more time for processing than will more routine requests.

Investigators who wish to study ephemeral properties may request a waiver of the twelve-month waiting period; however, such requests will be referred automatically to the relevant co-chiefs. If such a request is approved, the investigator will join the shore-based contributors to the shipboard science effort, and will incur the obligations thereof (see section 1).

C. Samples will not be provided until the requestor assures the Curator that funding for the proposed research is available or unnecessary. If a sample request is dependent in any way on proposed funding, the Curator is prepared to provide the proposed funding organization with information on the availability (or potential availability) of suitable samples.

D. Investigators who receive samples incur the following obligations:

(1) To publish significant results promptly; however, no contribution may be submitted for publication prior to twelve (12) months following the termination of the relevant leg unless it is approved and authored by the entire shipboard party.

(2) To acknowledge in all publications that the samples were supplied through the assistance of the international Ocean Drilling Program and others as appropriate.

(3) To submit four (4) copies of reprints of all published works to the Curator, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A. These reprints will be distributed to the repositories and to the ship. All reprints received will be logged in an on-line bibliographic data base.

(4) To submit all final analytical data obtained from the samples to the Data Librarian, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A. Please consult announcements in the *JOIDES Journal* or call (409-845-2673) for information on acceptable data formats. Investigators should be aware that they may have other data obligations under the National Science Foundation's Ocean Science Data Policy or under relevant policies of other funding agencies which require submission of data to national data centers.

(5) To return all unused or residual samples, in good condition and with a detailed explanation of any processing they may have undergone, upon termination of the proposed research. In particular, all thin sections and smear slides manufactured on board the vessel or in the repositories are to be returned to the Curator. Paleontological materials may be returned either to the Curator at ODP or to one of the designated micropaleontological reference centers.

Failure to honor these obligations will prejudice future applications for samples.

E. Cores are available for examination by interested parties at the repositories. Investigators are welcome to visit the repositories in order to inspect cores and to specify sample locations when that is required for their research; however, time and space in the workrooms are limited, so advance appointments are required. Occasionally, the space may be fully booked several weeks in advance, so investigators are urged to call for appointments well ahead in order to avoid disappointment. Only the Curator or his delegate may actually remove samples from the cores.

F. A reference library of thin sections, smear slides, and archive photographs is maintained in the repositories for the use of visiting investigators. All thin sections and smear slides produced on board the ship or in repositories belong to this library.

### 3. *Distribution of Samples to Micropaleontological Reference Centers*

As a separate and special category of repository activity, selected samples are distributed to micropaleontological reference centers, where the prepared material may be studied by visitors. Foraminifers, calcareous nannofossils, and diatoms can be viewed; radiolarians will be prepared in the future. The present centers are (1) U.S. East Coast: Lamont-Doherty Geological Observatory, Palisades, NY 10964 (Ms. Rusty Lotti; telephone, 914-359-2900; telex, 7105762653 LAMONTGEO); (2) U.S. National Museum: Smithsonian Institution, Washington, D.C. 20560 (Dr. Martin Buzas; telephone, 202-357-1390; telex, 264729); (3) U.S. Gulf Coast: Texas A&M University, Department of Oceanography, College Station, TX 77843 (Dr. Stefan Gartner; telephone, 409-845-8479; telex, 792779/ODP TAMU); (4) U.S. West Coast: Scripps Institution of Oceanography, La Jolla, CA 92093 (Dr. William Riedel; telephone, 619-534-4386); telex, 910337127 IUC WWD SIOSDG); (5) Western Europe: Natural History Museum, CH-4001 Basel, Switzerland (Mr. J. B. Saunders; telephone, 061-29-55-64); (6) U.S.S.R.: Institute of the Lithosphere, Staromonet 22, Moscow 109180, U.S.S.R. (Dr. Ivan Basov; telephone, 231-48-36); (7) Japan: National Science Museum, Department of Geology, 3-23-1 Hyakunio-cho, Shinjuku-ku, Tokyo 160, Japan (Dr. Y. Tanimura; telephone, 03-364-2311; telemail, 03-364-2316); (8) New Zealand: New Zealand Geological Survey, P.O Box 30368, Lower Hutt, New Zealand (Dr. Tony Edwards; telephone, (04) 699059).

Further details concerning the micropaleontological reference centers are reported periodically in the *JOIDES Journal*.

### 4. *Distribution of Samples for Educational Purposes*

Samples may be available in limited quantities to college-level educators for teaching purposes. Interested educators should request application forms from the Curator, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A. Requestors are required to specify preferred sample size and location, to make a very clear statement of the nature of the course work in which the samples will be used, to explain how the samples will be prepared and how they will be used in the classroom, to explain in detail why similar materials derived from outcrops or dredge hauls cannot be used (it is NOT acceptable to argue that it requires less effort for the requestor to obtain samples from ODP than to assemble them from other sources), and to certify that funds are available to prepare the materials for classroom use. In general, only samples of materials which are abundant in the collection and which are in little demand for research purposes should be requested for educational purposes. The Curator will not approve requests for materials which are limited in supply or for which demand (real or potential) is great, including most paleontological materials.

### 5. *Distribution of Data*

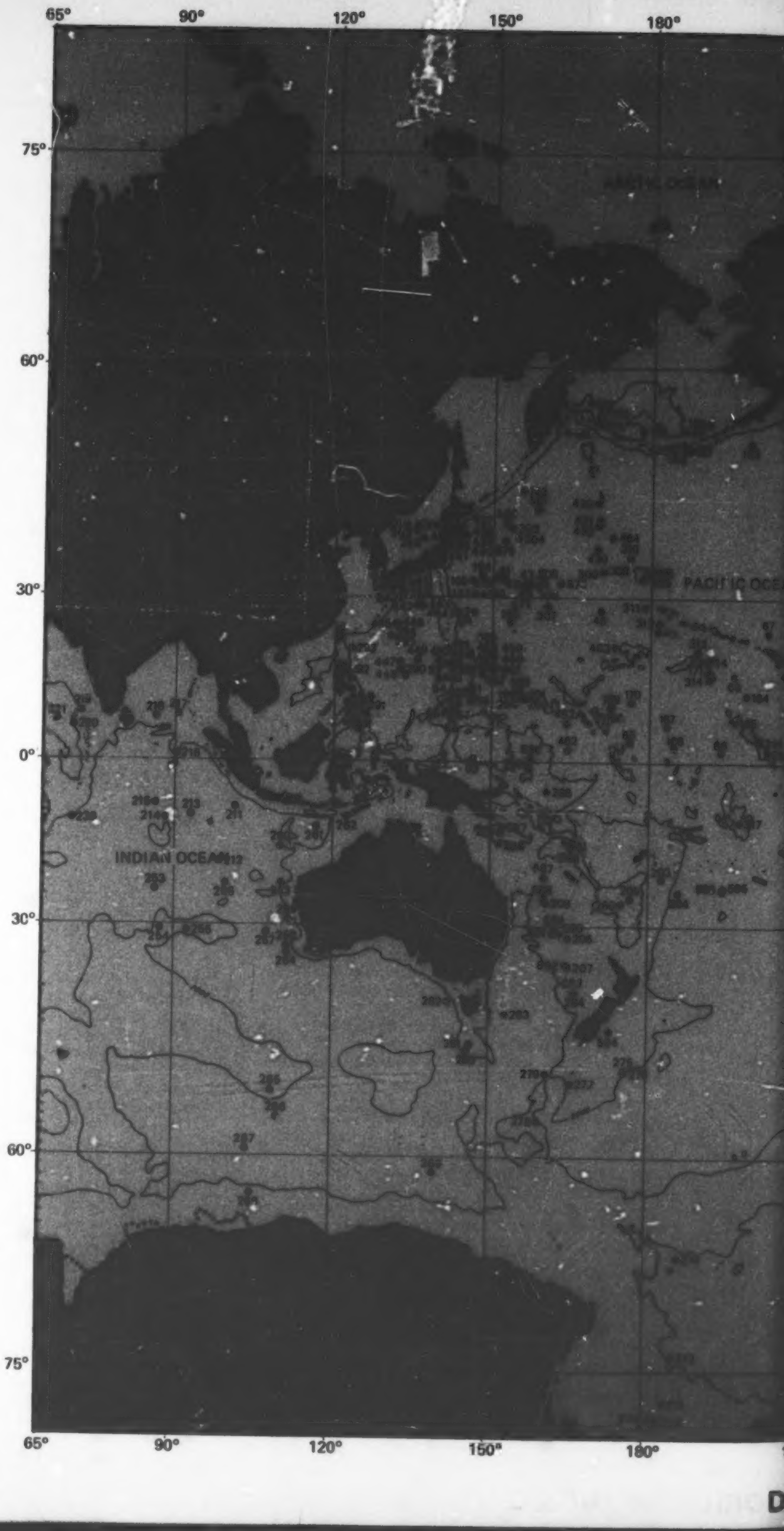
The Deep Sea Drilling Project and the Ocean Drilling Program have routinely captured much of the data generated on board ship and published in Program reports. Additionally, data supplied by investigators who have received samples are incorporated into the data bases, so data sets which are larger than can be published are available to investigators. Magnetic, downhole-logging, seismic-reflection, bathymetric, and other data collected by the drilling vessel become available for distribution to investigators at the same time as core samples.

Requests for ODP and DSDP data should be addressed to the Data Librarian, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840, U.S.A. Many varieties of DSDP data are included in ODP data bases. Information on sources of DSDP data is available from the ODP Data Librarian.

A charge will be made to recover material expenses greater than $25.00 incurred in filling individual requests. If required, estimates of charges can be furnished before the work is performed.

## Drilling locations

| Leg | Location | Sites |
|---|---|---|
| Phase 1 1968–1970 | | |
| 1 | North Atlantic | 1–7 |
| 2 | North Atlantic | 8–12 |
| 3 | South Atlantic | 13–22 |
| 4 | Central Atlantic | 23–31 |
| 5 | North Pacific | 32–43 |
| 6 | North Pacific | 44–60 |
| 7 | Central Pacific | 61–67 |
| 8 | Central Pacific | 68–75 |
| 9 | Central Pacific | 76–84 |
| Phase 2 1970–1972 | | |
| 10 | Gulf of Mexico | 85–97 |
| 11 | North Atlantic | 98–108 |
| Re-entry trials | | 109–110 |
| 12 | North Atlantic | 111–119 |
| 13 | Mediterranean | 120–134 |
| 14 | Central Atlantic | 135–144 |
| 15 | Caribbean | 146–154 |
| 16 | Central Pacific | 155–163 |
| 17 | Central Pacific | 164–171 |
| 18 | North Pacific | 172–182 |
| 19 | North Pacific | 183–193 |
| 20 | North Pacific | 194–202 |
| 21 | Coral Sea | 203–210 |
| 22 | Indian Ocean | 211–218 |
| 23 | Arabian Sea | 219–230 |
| 24 | Indian Ocean | 231–238 |
| 25 | Indian Ocean | 239–249 |
| Phase 3 1972–1975 | | |
| 26 | Indian Ocean | 250–258 |
| 27 | Indian Ocean | 259–263 |
| 28 | Antarctic | 264–274 |
| 29 | Tasman Sea | 275–284 |
| 30 | South Pacific | 285–289 |
| 31 | North Pacific | 290–302 |
| 32 | North Pacific | 303–313 |
| 33 | North Pacific | 314–318 |
| 34 | South Pacific | 319–321 |
| 35 | South Pacific | 322–325 |
| 36 | South Atlantic | 326–331 |
| 37 | North Atlantic | 332–335 |
| 38 | Arctic | 336–352 |
| 39 | Atlantic | 353–359 |
| 40 | South Atlantic | 360–365 |
| 41 | South Atlantic | 366–370 |
| 42A | Mediterranean | 371–378 |
| 42B | Black Sea | 379–381 |
| 43 | North Atlantic | 382–387 |
| 44 | North Atlantic | 388–392 |
| 44A | North Atlantic | 393–394 |
| IPOD 1 1975–1983 | | |
| 45 | North Atlantic | 395–396 |
| 46 | North Atlantic | 396A–396B |
| 47 | North Atlantic | 397–398 |
| 48 | North Atlantic | 399–406 |
| 49 | North Atlantic | 407–414 |
| 50 | North Atlantic | 415–416 |
| 51A | North Atlantic | 417–417A |
| 51B | North Atlantic | 417B–417D |
| 52 | North Atlantic | 417D–418A |
| 53 | North Atlantic | 418A–418B |
| 54 | Central Pacific | 419–429 |
| 55 | North Pacific | 430–433 |
| 56 | North Pacific | 434–437 |
| 57 | North Pacific | 438–441 |
| 58 | North Pacific | 442–446 |
| 59 | North Pacific | 447–451 |
| 60 | North Pacific | 452–461 |
| 61 | Central Pacific | 462 |
| 62 | North Pacific | 463–466 |
| 63 | North Pacific | 467–473 |
| 64 | Gulf of California | 474–481 |
| 65 | Gulf of California | 482–485 |
| 66 | Central Pacific | 486–493 |
| 67 | Central Pacific | 494–500 |
| 68 | Central Pacific | 502–503 |
| 69 | Central Pacific | 504–505, 501 |
| 70 | Central Pacific | 506–510, 504B |
| 71 | South Atlantic | 511–514 |
| 72 | South Atlantic | 515–518 |
| 73 | South Atlantic | 519–524 |
| 74 | South Atlantic | 525–529 |
| 75 | South Atlantic | 530–532 |
| 76 | North Atlantic | 533–534 |
| 77 | Caribbean | 535–540 |
| 78 | North Atlantic | 541–543, 395A, B |
| 79 | North Atlantic | 544–547 |
| 80 | North Atlantic | 548–551 |
| 81 | North Atlantic | 552–555 |
| 82 | North Atlantic | 556–564 |
| 83 | Central Pacific | 504B |
| 84 | Central Pacific | 565–570 |
| 85 | Central Pacific | 571–575 |
| 86 | North Pacific | 576–581 |
| 87 | North Pacific | 582–584 |
| 88 | North Pacific | 581 |
| 89 | Central Pacific | 585–586, 462A |
| 90 | South Pacific | 587–594 |
| 91 | Central Pacific | 595–596 |
| 92 | Central Pacific | 597–602, 504B |
| 93 | North Atlantic | 603–605 |
| 94 | North Atlantic | 606–611 |
| 95 | North Atlantic | 612–613, 603 |
| 96 | Gulf of Mexico | 614–624 |



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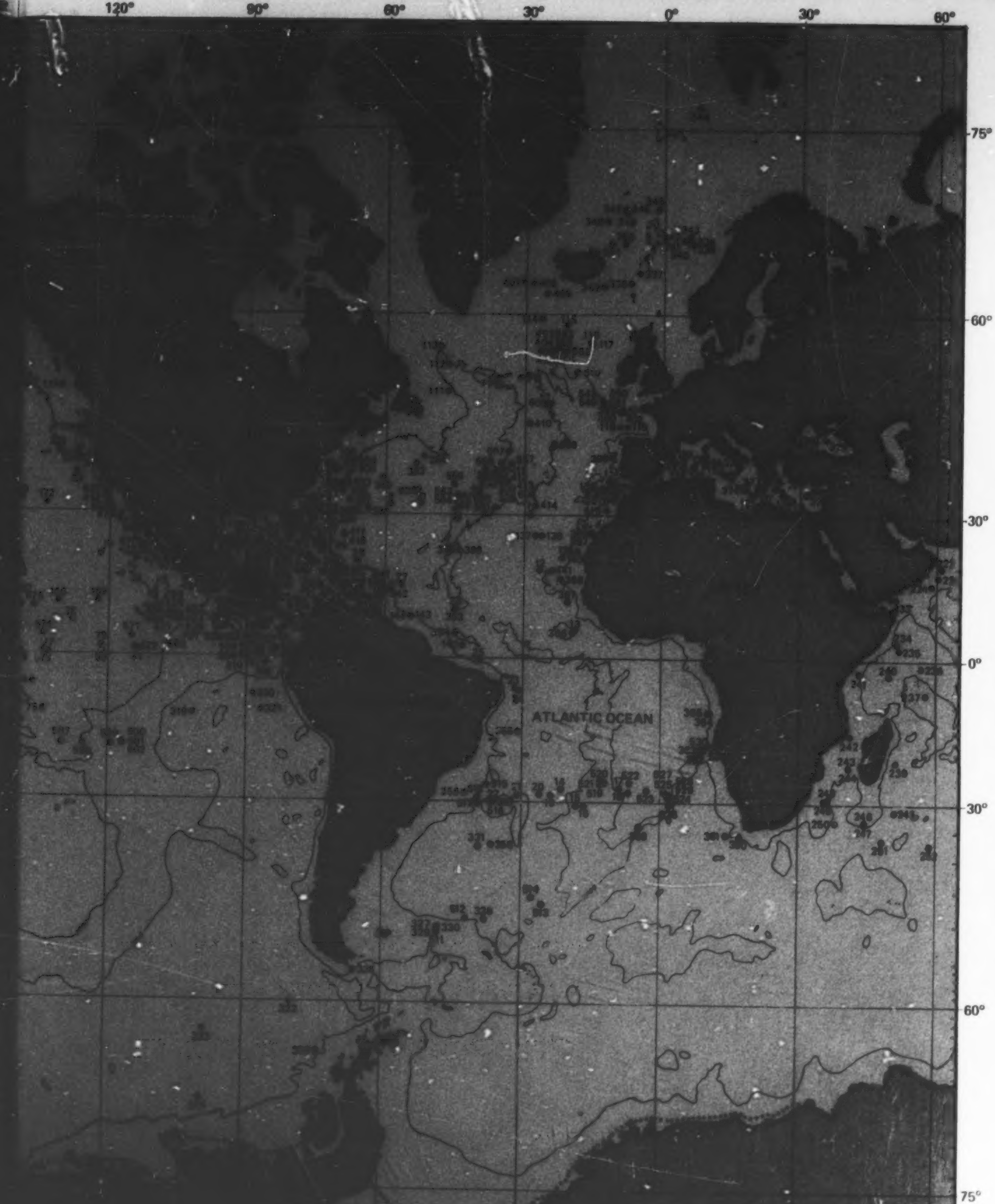
120°
90°
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30°
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75°
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30°
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ATLANTIC OCEAN
120°
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60°

## SEA DRILLING PROJECT